Assessing Organic Farm Nutrient Management

by

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ABSTRACT

The United States Department of Agriculture provides requirements for a farm operation to become certified organic, but how do these regulations influence nutrient management on organic farms? There is insufficient evidence to show if the current regulations on nutrient sourcing and application are feasible and effective. An online survey was administered to owners and operators of organic farms. Survey respondents were offered a free soil test as an incentive to participate and to compare their practices and soil quality. Assessing the current nutrient management under organic regulations provides information to help assess the sustainability of their nutrient management practices. Early data suggest that organic farmers may most often be overapplying and creating legacy sources with this key resource.

TABLE OF CONTENTS

Page

CHAPTER

CHAPTER Page

APPENDIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Organic farming, a method promoted to meet the objectives of sustainable agriculture, is developing rapidly in countries that practice organic production (Reddy 2011). The United States Department of Agriculture (USDA) has requirements for a farm operation to become certified organic, but how do these regulations influence nutrient management? While there is current research assessing other aspects of the certified organic regulations, there is not sufficient evidence that the current nutrient requirements are feasible and effective for ensuring sustainable nutrient management. In fact, little data exists on what the current organic farming practices are. The term “organic” is often coupled with the idea of “sustainability.” It should be noted that organic production does not necessarily mean sustainable production, (Rigby and Cáceres 2001). The understanding of how to properly manage a farm is important, not only for the sustainability of the farm itself, but also for the impacts farms may have on their surrounding environment. This research intends to fill the gaps in the literature surrounding whether current organic farming practices promote environmental sustainability.

Nutrient Management and Organic Farming

While there are many aspects of farm sustainability, this thesis focuses on a portion of environmental sustainability related to farming – nutrient management. USDA certified organic regulations only allow the use of organic fertilizers, creating an intrinsic limitation for the operator of the farm. It is also important to apply the right nutrients at the right time, the right dosage, and within the correct balance relative to other important nutrients (Johnston and Bruulsema 2014). Organic fertilizer options are often imbalanced, having a lower nitrogen to phosphorus ratio than crops require. Nitrogen is a consistent limiting factor in this process and can make it difficult for farmers to create and maintain that proper nutrient balance (Berry et al. 2006). Farmers restricted to fertilizers with improper nutrient balances may either under fertilizer nitrogen, or overfertilize phosphorus. Overfertilization is a common occurrence within farming systems today with significant impacts on the environment (Paerl, Otten, and Kudela 2018). Eutrophication is a common environmental health issue that is often driven by the overfertilization of farmland. The excess nutrients that are not utilized properly by crops can lead to leaching into groundwater and runoff into surface waters. When this runoff enters nearby bodies of water, the surplus in nutrients creates an environment which may facilitate algal blooms. This increase in algal blooms lowers the dissolved oxygen content in the water and can cause harm to aquatic life and the ecosystem as a whole (Anderson, Glibert, and Burkholder 2002).

Sustainable Nutrient Management

Since crops vary in what specific nutrients they need, it is important to plan what crop will be planted to accommodate their exact needs (Johnston and Bruulsema 2014). These nutrients include primarily nitrogen, phosphorus, and potassium; however, nitrogen and phosphorus are the key nutrients covered by this study. This planning can include completing soil testing before planting, leaf testing during the growing season, and testing composts, manures, or other organic fertilizers before application. Farmers may also need to account for the use of green manures or rotational legumes as a source of nitrogen and nutrients with irrigation water. Typically, it is recommended that farmers test their soils before each crop or planting season in order to determine the exact nutrient inputs needed. Soil samples should be taken at multiple locations throughout each field to ensure consistency and minimize error. These samples are taken by using a clean soil auger or similar tool to retrieve a soil profile from about one to six inches deep (NRCS 2002). This way, the data is not skewed by capturing nutrients that may be accumulated, for example, on the surface of the soil. Preserved in a plastic bag or other airtight container, these samples should be taken to a lab where they are able to test for nitrogen and phosphorus as well as other nutrients and soil characteristics such as pH and organic carbon content. Leaf analysis accomplishes a similar goal compared to soil testing but is usually more destructive as the leaves must be broken off and taken to a lab. There are now less destructive methods being developed, such as Near Infrared spectroscopy (NIRS), which can monitor the nutrients of plants in real-time (Prananto, Minasny, and Weaver 2020). Knowing exactly what a crop needs is not enough to achieve efficient nutrient management practices; it is also important to test what inputs of nutrients are being used (Johnston and Bruulsema 2014). For instance, manure and compost do not have known nutrient compositions. To apply these inputs in the correct amounts needed by a crop, it is important to also test these inputs. Similarly, legumes are commonly used to supplement the nitrogen composition of the soil as they fixate their own nitrogen

(Berry et al. 2006). Since nitrogen is a consistent limiting factor in nutrient management, the use of legumes can be beneficial. When using legumes as green manure, it is again important to test the nutrient composition to maintain the appropriate levels in the soil. It is of note that in arid or semi-arid farming conditions, green manures may not be a feasible nitrogen option due to the extra irrigation requirements.

While it is key to understand how operations apply fertilizers for environmental sustainability, it is also important to understand what application practices support optimal plant growth. A study done in 1996 revealed that a nitrogen to phosphorus ratio of 15:1 is optimal for most plants (Luo et al. 2016). In this case a ratio of 16 or higher would be phosphorus limiting and a ratio of 14 or lower would be nitrogen limiting. When analyzing soil samples, this will provide useful insight as to which nutrient is limited.

Organic Farming Requirements

For an operation to be certified organic, the producer must manage crops through preventative measures first, and then look into inputs (Organic Food Production Act Provisions 2022). For instance, nutrients should be managed through methods such as crop rotation, cover crops, and the application of plant and animal materials. If the operator wants to apply other inputs, they must first be approved through a certifier. Certified organic operations may use the Organic Materials Review Institute’s (OMRI) certified materials including fertilizer, pesticides, and more, but other than that, operations would have to rely on organic sources such as manure, compost, and green material. The OMRI certified materials have a known content for each nutrient (similar to inorganic options), making it easier for operators to apply the correct amount, but with fertilizers such as organic manure and compost, the operator would have to consistently test their source to know the nutrient content. If not done, this can lead to improper application of nutrients. The process is similar for other aspects of crop production. For pest control, preventative measures must be attempted first. If this fails, then a pesticide application can be used, but only after approval from the certifier (Organic Food Production Act Provisions 2022). To determine the allowable inputs, in short, they must be organic; however, there is a long list of allowable synthetic inputs as well as a list of prohibited organic inputs. These lists are called the National List of synthetic substances allowed for use in organic crop production and the National List of organic substances prohibited in organic crop production (Organic Food Production Act Provisions 2022). To maintain organic certification, the operation will complete an annual review and inspection. The key requirements are that the land has been free of prohibited substances for 36 months prior to harvest, all inputs must be documented, and all receipts for purchasing those inputs must be saved (Organic Food Production Act Provisions 2022). In terms of the cost of achieving and maintaining organic certification, there is a wide range of costs depending on the certifying agent, the size of the operation, the type of operation, and the complexity of the operation. There is usually an application fee, an annual renewal fee, and an annual inspection fee. These costs could be anywhere from hundreds to thousands of dollars (United States Department of Agriculture 2022). This could be a possible barrier from self-identifying organic but non-certified farms from becoming certified. While our study did not require participants to be certified organic, it is widely assumed that other operations that self-identify as organic would be adopting similar methods, especially with respect to nutrient inputs. Another possible barrier could be a lack of awareness or education on organic farming and the problems it poses in terms of environmental sustainability. As shown in previous research, many farmers start farming operations with little educational background (Patidar and Patidar 2015). Most of the experience associated with farming is through experience living on a farm or having family members and/or friends that manage farming operations. There is often no previous experience at all. This might suggest that farming practices are not grounded in the science behind it and are usually not very calculated. This leads to a wide range of variable and unregulated practices. By assessing nutrient management practices under the organic regulations, this study will bring awareness to the duality of organic and sustainable practices.

CHAPTER 2

PREVIOUS WORK

Among producers and consumers is a common perception that organic and sustainable farming are one in the same; however, that may not always be the case (Trewavas 2001). An organic farm may definitely employ sustainable practices but being an organic farm alone does not automatically qualify that farm as sustainable, especially considering the multi-faceted nature of sustainability. Conversely, conventional agricultural systems may employ numerous sustainable practices without qualifying as “organic”.

Previous work has investigated the “widespread belief that low-yielding organic agricultural systems are more friendly to the environment and more sustainable than high-yielding farming systems” (Trewavas 2001). The practice of organic farming was developed based on the philosophical views of Rudolf Steiner and Lady Eve Balfour and has little scientific evidence showing it is any better than other forms of agriculture. Organic farming prohibits the use of synthetic herbicides, pesticides, and fertilizers. The goals of organic farming to mitigate synthetic pollution and human, animal, and environmental health effects are valid, but the regulations put in place in an attempt to progress these goals have little supporting evidence. In reality, organic farming has been found to result in a less cost effective process (Trewavas 2001). In many cases the cost input is much higher and results in a lower yield than conventional farming. This demonstrates that organic farming and sustainable farming do not always work together as it can create an insufficient use of land and other resources.

There are certain practices that conventional farming utilizes that are often overlooked as a result of the push for organic (Trewavas 2001). For instance, conventional farming more often has higher yields per land area compared to organic farming. This aids in land conservation efforts and species diversity by protecting wildlife habitats. These low-cost high-yield products often result in a lower cost for the consumer as well. Likewise, in an effort to avoid synthetic herbicides, organic farmers often employ mechanical weeding. This method has the potential to damage the surrounding habitats and wildlife such as bird nests, worms, and other invertebrates that live in the dirt. Mechanical weeding also commonly utilizes fossil fuels – a pollutant detrimental to the mitigation of climate change (Trewavas 2001). These effects may also lead to the degradation of the soil due to the harm of the surrounding worms and other animals and bugs that aid in maintaining the health of the soil (Trewavas 2001). By employing conventional methods in a smarter way, sustainable ideals can be supported while also maintaining crop yield. For instance, "a single treatment with innocuous herbicide, coupled with no-till conventional farming, avoids this damage and retains organic material in the soil surface," (Trewavas 2001). Also common with organic farming is the use of organic manure to maintain soil nutrient levels. The use of manure can be beneficial in the fact that it maintains soil fertility and beneficial amounts of earthworms; however, there is also the risk of impacting human health through the spread of *E. coli* and other feces-borne illnesses. Another issue prevalent in organic farming practices is the prohibition of soluble mineral salts. Since the minerals taken up by crops must be recharged to maintain soil fertility, organic farmers often implement either or all of the following methods: legume nitrogen fixation, rainwater irrigation, and mineral recycling (Trewavas 2001). The issues outlined prior suggest that the mineral deficits are slow but are definitely increasing in organic farmland. Organic farms are intended to balance the production and use of manure and straw. In most cases, excess manure or straw is not available for use in repairing the nutrient deficit. Because of this, “many organic farms can become dependent on products that are conventionally produced with inorganic minerals,” (Trewavas 2001). Trewavas (2001) describes how these studies and “developments in the past 25 years have shown how conventional agriculture can be much more sustainable and environmentally friendly than organic farming.”

Further research has shown that “the desire for sustainable agriculture is universal, yet agreement on how to progress towards it remains elusive," (Rigby and Cáceres 2001). Achieving this goal is not truly possible as there is not a consensus on what it means for a farm to be sustainable. Many still hold the belief that “organic farming and sustainable agriculture are synonymous”, while “others regard them as separate concepts that should not be equated,” (Rigby and Cáceres 2001). A commonly accepted definition of sustainability states that the system is providing for the current generation without destroying the means of production for future generations (Rigby and Cáceres 2001). The idea of achieving true sustainability is a wicked problem that loops in the dilemmas of the economic, social, and economic realms. For the purpose of this study, the focus will be on environmental sustainability, and specifically the influence of nutrient management. In this sense, sustainability ideally maintains productivity while avoiding the depletion of resources and environmental health. That being said, "it is extremely difficult to determine whether certain agricultural practices are sustainable or not. It is only in retrospect that sustainable techniques can be truly identified," (Rigby and Cáceres 2001). This implies a constant reassessment and readjustment of the current agricultural practices.

"Despite there being a broad consensus among advocates of sustainable agriculture that the conventional approach to agriculture is inappropriate, there are significant differences regarding the type of farming practices which should be developed in order to approach sustainability," (Rigby and Cáceres 2001). As shown by Rigby and Cáceres (2001), it is easier to label something as unsustainable rather than sustainable. As the interest in sustainability is increasing, it becomes important to analyze what sustainability means as well as how to achieve sustainable practices. Since organic agriculture is often perceived as a way to achieve that goal, understanding the relationship between organic and sustainable practices becomes crucial. "Organic farming pre-dates all other approaches to "environmentally-friendly" agriculture (Scofield, 1986). Because of the high level of regulations compared to conventional farming, it is easy to assume that organic farming is more sustainable; however, the restriction of inorganic chemicals does not necessarily aid in environmental sustainability (Rigby and Cáceres 2001). The organic label does not automatically make a practice sustainable; however, it is possible for certain standards to overlap.

CHAPTER 3

METHODS

Hypotheses

Preceding the survey development, hypotheses were created to act as the direction and framework for the survey questions. Based on the literature and previous work, it was hypothesized that farmers are not applying nutrients in a calculated practice. More specifically, it was expected that farmers would not be conducting regular soil nutrient tests in order to properly calculate the necessary nutrient application rate. It was also theorized that phosphorus would more commonly be overfertilized, while nitrogen would be unfertilized. Because of the limitations on nutrient sources set in place by the USDA and because nitrogen is already a limiting factor in nutrient applications, it was expected that farmers would have a difficult time achieving the ideal nitrogen to phosphorus ratio of 15:1. Overall, it was hypothesized that farmers would not be able to effectively apply nutrients in the favor of both organic and sustainable practices. Table 1 shows a summary of the hypotheses made during the literature review portion of this study. The aim of this study is to provide insight as to what practices self-identified organic farms in the United States are engaging in. As an extension, this study investigates whether these practices are appropriate in promoting environmental sustainability as well as crop growth. These goals in combination with analyzing the feasibility of organic practices will be essential insight for future research.

Table 1. Research Questions and Hypotheses

RQ1:	What practices are self-identified organic farmers in the U.S. engaging in?
HQ1:	Organic farming operations tend to overfertilize phosphorus and underfertilize nitrogen.
HQ2:	Organic farms are not achieving the N:P ratio of 15:1 for optimal crop growth.
HQ3:	Organic farms will lack environmentally sustainable practices due to an education barrier.
HQ4:	Organic certified farming practices will be more sustainable than non-certified practices.

Survey and Distribution

To investigate the experience and effect of organic nutrient management, an online survey was administered to willing participants that either own or operate an organic farm. Based on literature review, past farming surveys, and expert assistance, a survey was created and distributed using the program *Qualtrics* (shown in Appendix A). This survey and forms of contact were submitted to and approved by Arizona State University's Institutional Review Board (STUDY00015071). A subsequent modification was made in order to share via social media. The original approval and the modification approval may be found in Appendices D and E. The scope of the survey was within the United States and was distributed by contacting larger organizations such as the Organic Trade Association and The Organic Center, which disseminated the survey to its members (Appendix F). The survey included questions involving on-farm nutrient management and other important factors (Appendix A). More specifically, the survey focused heavily on nutrient management practices, which include how and when fertilizers are applied, what fertilizers are applied, if nutrient calculations are being used, and if soil testing is part of that process. The survey questions were divided into five blocks: “Qualifiers,” “Defining your Operation,” “Water Management,” “Fertilizer Management,” and “Free Response”. The qualifying questions ensure that participants are 18 or older, and that they are the owner or operator of a crop-producing operation that identifies as organic. “Defining your Operation,” gathered information on the location, size, profit, and other details of the operation. The “Water Management” section asked questions involving irrigation management practices such as the source of irrigation water and if the nutrients of these waters are tested. Information such as fertilizer inputs, application rates, and soil testing procedures was gathered in the “ Fertilizer Management” portion of the survey. Finally, the free response questions sought to provide insight into the experiences and motivations of the participants as well as provide a space for them to explain any practices they felt were not represented in the survey.

Soil Testing

The survey participants were compensated with a free soil test. Testing was done by Motzz Laboratory, Inc. This testing was free on the participant’s end as an incentive for taking the survey and was funded by the USDA. These soil tests analyzed total N, Nitrate-N (NO3-N), Phosphate-P (PO4-P), and total organic carbon. This nutrient data combined with survey responses provided further insight into answering the research questions. A flat rate envelope containing materials and instructions for sample collection was sent out to each participant so that they could take their own sample and return it easily. These materials included a plastic bag to contain the sample, sampling instructions (Appendix B), a sample details form (Appendix C), and a flat rate shipping box with prepaid shipping. All materials were labeled with a participant ID to remove any connection between personal information and results. Upon arrival, samples were taken to Motzz Laboratory for testing (Table 2). Once results were available, they were forwarded to the participants via email along with the information specific to their local crop extension.

Table 2. Motzz Laboratory Testing Methods

Parameter	**Total N**	**NO3-N**	**PO4-P**	**Total Organic Carbon**
Method	Combustion	Cd-Reduction	Olsen	AOAC 972.43

Demographics of Survey Participants

For the purpose of this study, it was important to assess the location, profit, experience, and education of the farmers to be able to understand if these factors may have influences certain management decisions. Understanding the demographics of the survey pool was also key in determining specific correlations between the farmer and the results. In total, 19 survey responses were recorded, with 18 of them agreeing to submit soil for testing. It should be noted that not all participants answered all of the survey questions. Due to the qualifications of this survey, all participants were over the age of 18 and were the farmer/operator of an organic operation within the United States that grows crops. The organic operation was not required to be certified but could self-identify as organic if they operated under these conditions without official certification. Figure 1 shows a density map of the participants, with the majority being located in Montana due to the location of the organizations that agreed to the distribution.

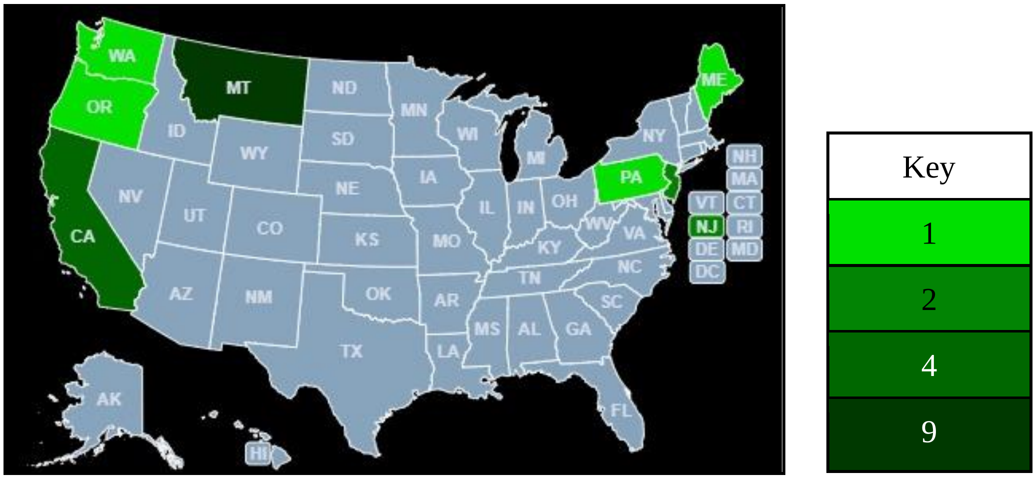

Figure 1. Farm Location Density Map

The farm growing crops the longest began in 1970, while the newest farm began in 2021, giving a range of 51 years. The average age of the farms is about 19 years; however, most of the farms are 11 years old. This data shows a standard deviation of about 16 years. In terms of overall experience, however, the majority of farming experience is in organic farming compared to conventional agriculture (Figure 2).

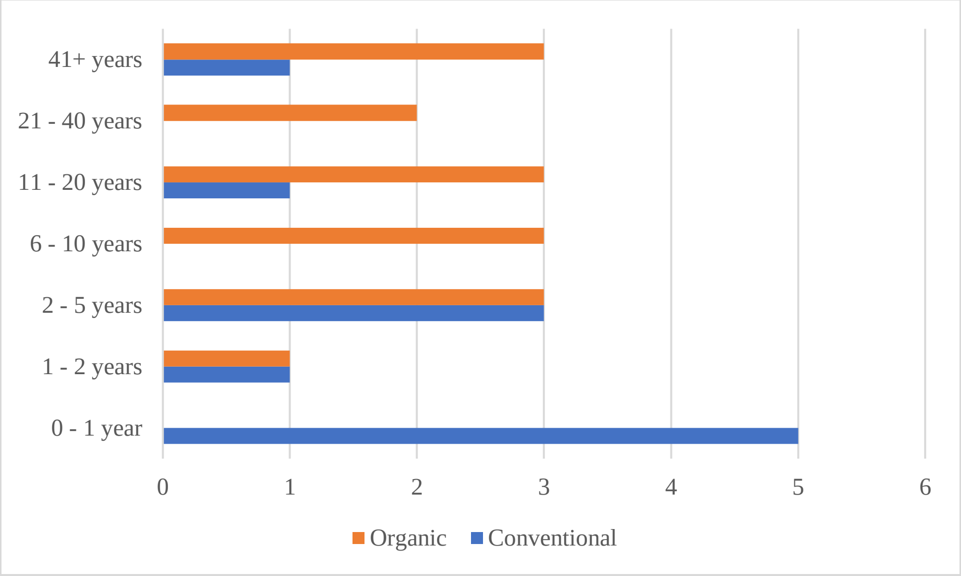

Figure 2. Years of owner/operator experience in organic versus conventional farming

Three of the participants stated that they have a B.S., M.S., or PhD degree in agriculture, or an agricultural-related field and 1 participant has a B.A. or associated degree in this area. 10 participants indicated that they grew up and/or lived on a farm (Figure 3).

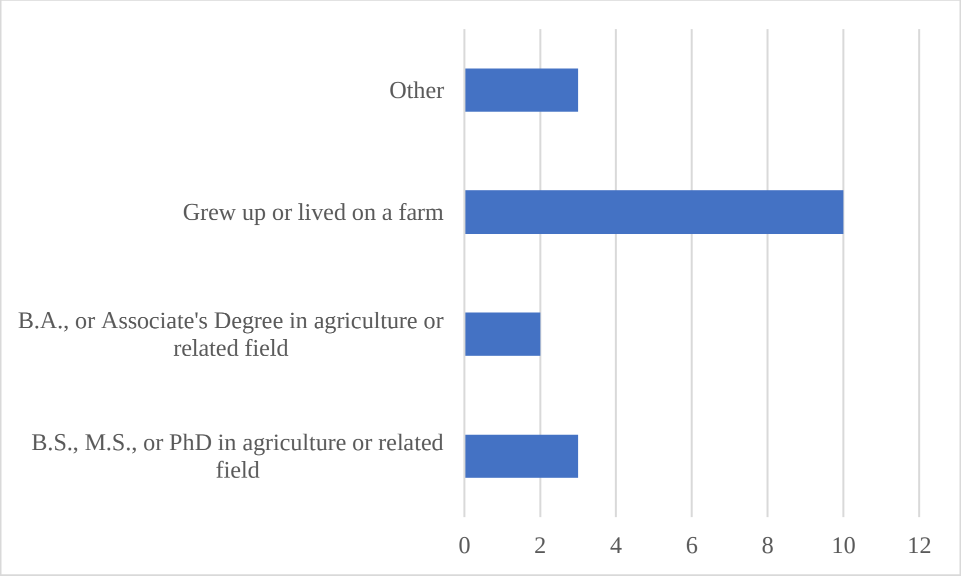

Figure 3. Owner/operator education and previous experience in farming

According to the survey, 16 of the 19 farms are USDA Certified Organic, while the other 3 farms are not certified organic, but self-identify as organic. Two of these three farms indicated that they are not certified organic because of the financial requirements to become certified. Two farms also indicated that the time and effort to become certified was a challenge. Only one farm indicated that the challenge to become certified was due to the lack of information on how to become certified. Despite this, however, 12 of the farms indicated that they would like to increase their organic agricultural production over the next 5 years. Five of the farms wanted to maintain their current level of agricultural production. Only one farm indicated that they would like to decrease their organic agricultural production. One farm did not have a plan. A summary of these results is seen in Figures 4 and 5.

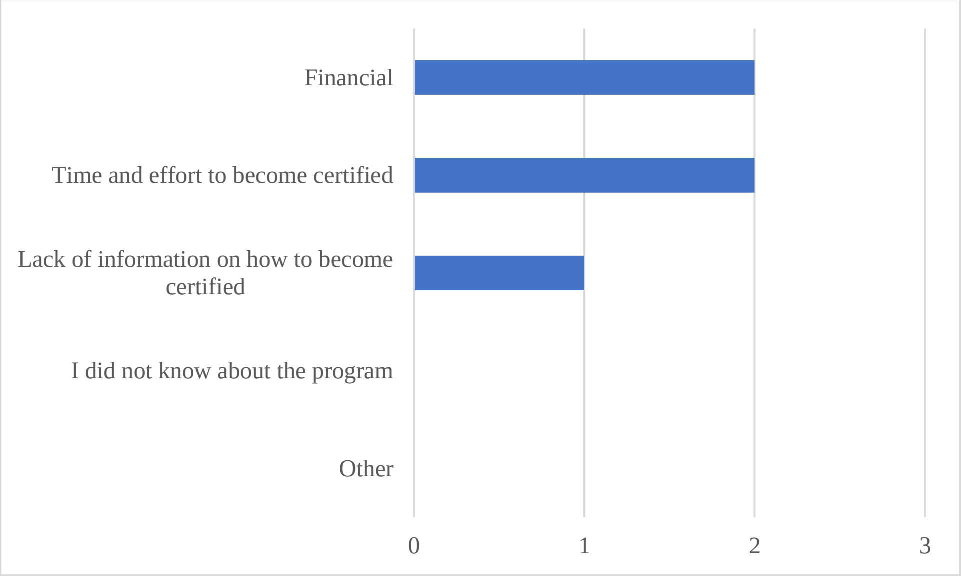

Figure 4. Barriers to obtaining USDA Organic certification

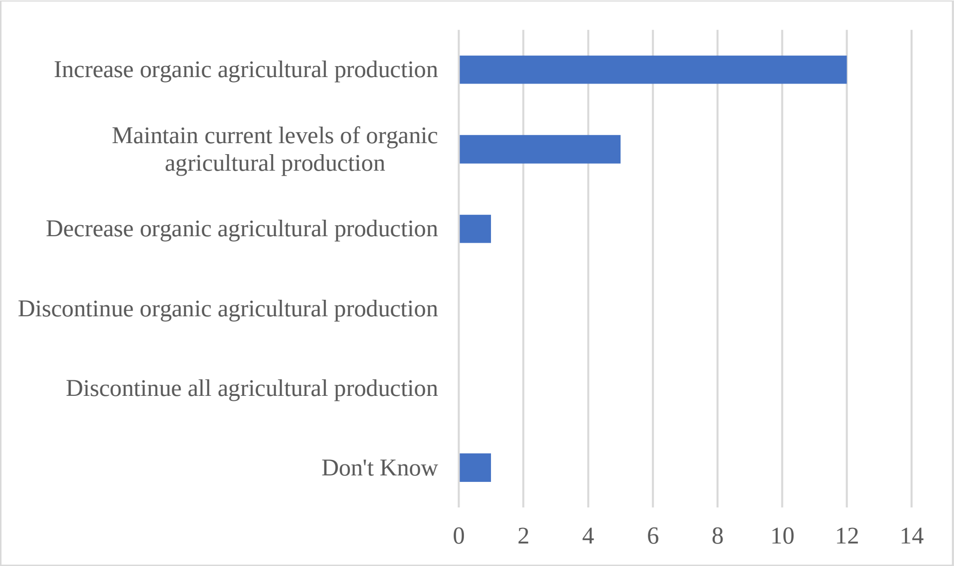

Figure 5. Operation’s 5-year estimation of change in organic production

The range of operation size varies greatly (Figure 6). 12 of the operations are smaller than 50 acres while seven of them are 50 acres or more. The majority of these farms were rural while only 2 of the 19 farms were suburban/peri-urban. None of the farms surveyed were considered urban (Figure 7).

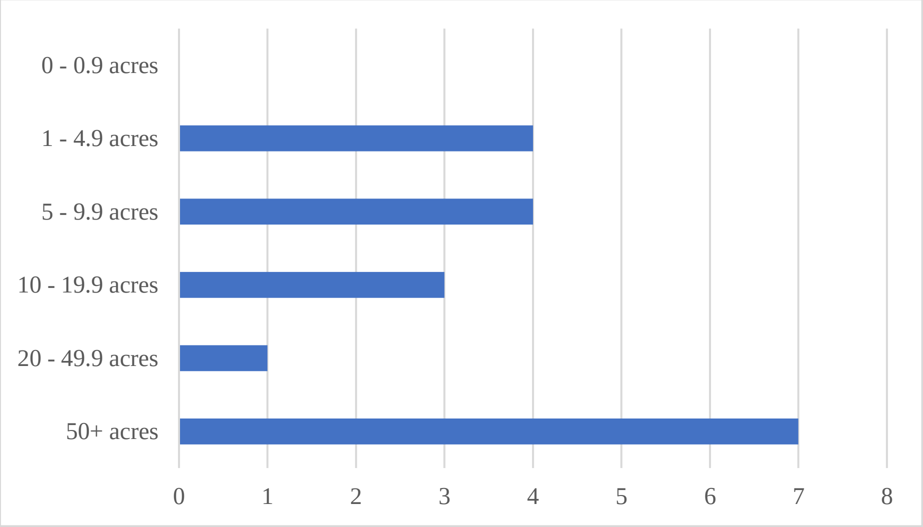

Figure 6. Farm size (acres)

The profit from the crops sold also varies widely as seen in Figure 7. Only one farm is non-profit, while 13 of the farm's gross sales are $100,000 or less. Only 4 farms profit over $100,000; however, 11 of the 19 farms claimed this was not their only source of income and was supplementary.

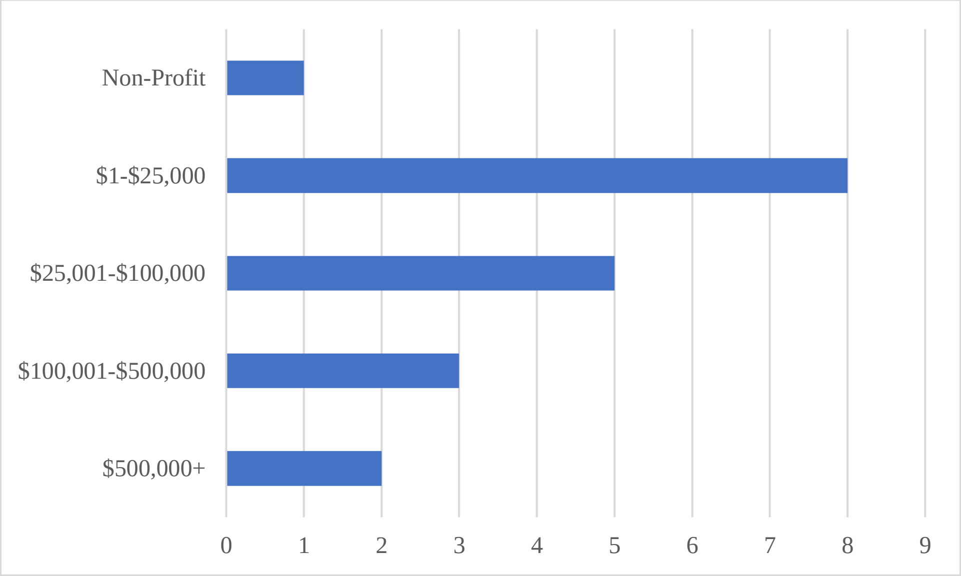

Figure 7. Operation's gross sales

The majority of farms produced 5 or more crops at a time (Figure 8). The crops grown on these farms were either horticulture crops such as fruits, nuts, vegetables, herbs, and spices, or field crops such as cereals, oilseed, pulses, and forage. No farms surveyed produced ornamental horticulture or landscaping crops (Figure 9).

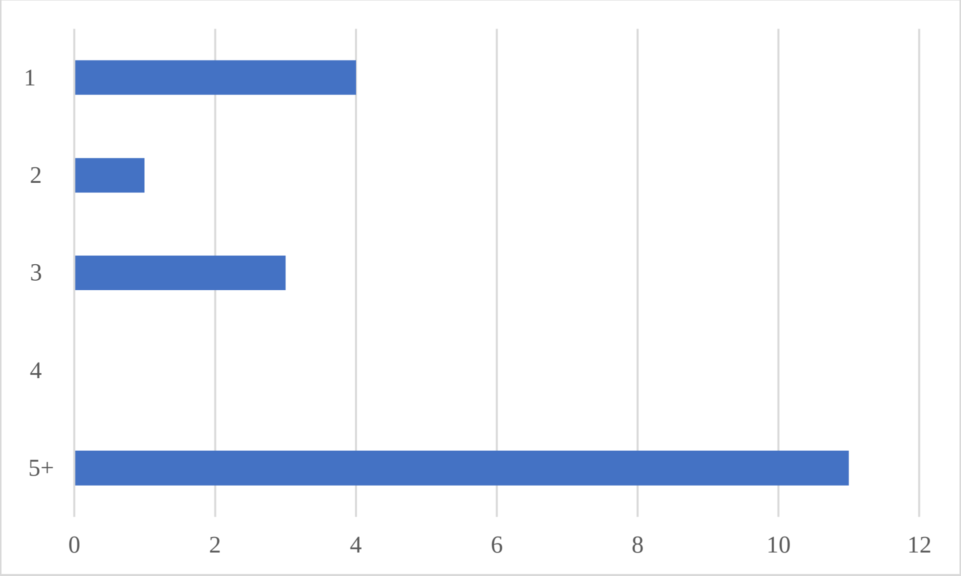

Figure 8. Number of crops grown by each farm

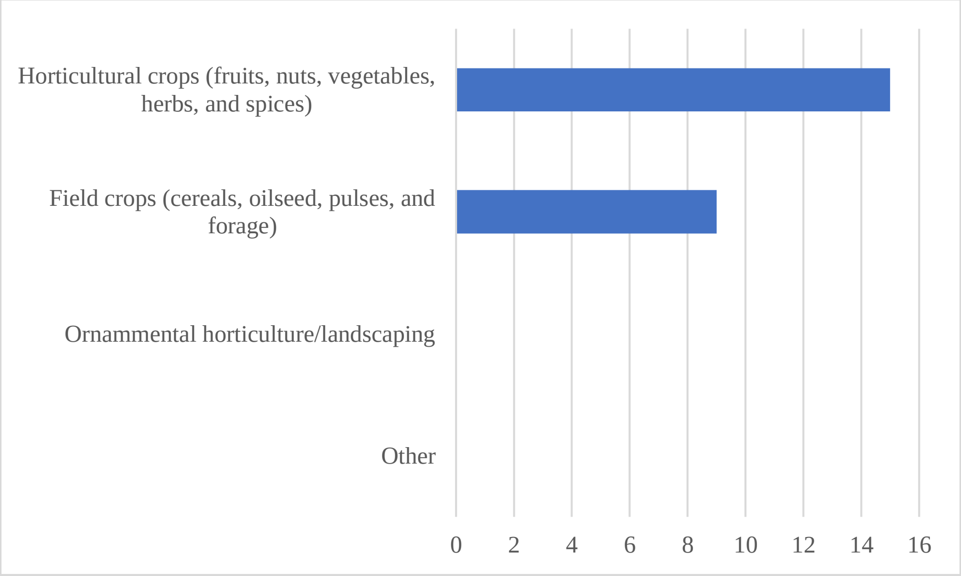

Figure 9. General categories of crops grown by surveyed farmers

Data Analysis

First, the general farming practices of the participants reviewed with the use of descriptive statistics. This information provides insight as to how certain demographics and characteristics of an operation influence management practices. The results of this survey were analyzed along with their respective soil samples, when available, to determine the viability of participants' farming practices. Determining environmental sustainability of these practices was based on past literature recommendations for best practices. To confirm or refute the hypotheses (Tables 4 and 5), t-tests, Chi-squared, and Fisher's-Exact tests were used. These statistical tests can help support study hypotheses. The Chi-squared test is used to determine if there is a statistically-significant difference between expected frequencies in categories from contingency tables created from two categorical variables. The Chi-squared test was completed in R Studio using the function "chisq.test." The data from the surveys was compiled into a CSV and then read into R Studio. For example, to test if there is a correlation between certification status (Certified/Not Certified) and if the participant has a soil testing plan (Yes/No), the code follows the format:

```
table(data$CertificationStatus,data$SoilTestingPlan)
chisq.test(data$CertificationStatus,data$SoilTestingPlan)
```

The “table” function produces a Table 3.

Table 3. Chi-Squared Frequency Table

	No	Yes
Certified	5	8
Not Certified	2	1

This table describes how many certified or not certified farms do or do not have a soil testing plan. The “chisq.test” uses this to determine if there is a difference between observed and expected frequencies in each cell of the contingency table. This test is only valid if the frequency of any group is 5 or greater. When there are frequencies of less than 5, the Fisher’s exact test was used instead with the “fisher.test” function as shown:

fisher.test(data$CertificationStatus,data$SoilTestingPlan)

Using either test depending on the conditions of the table produced, the *p*-value was determined for the test based on the associated test statistic. This *p*-value was used to either accept or reject the null hypothesis. If the *p*-value is less than 0.05, the null hypothesis is rejected. The null and alternative hypotheses for this test are as follows:

H_0: *The two variables are independent*

H_1: *The two variables are dependent*

For this example, the *p*-value was 0.55, therefore rejecting the null hypothesis and concluding that the observed frequencies were not statistically different from the expected frequencies for the sample. The hypotheses tested using the chi-squared test are shown in Table 4.

Table 4. Chi-Squared Hypotheses

HQ1:	Certified farms are more likely to have a soil testing plan.
HQ2:	Certified farms are more likely to use soil testing results to adjust fertilizer application.
HQ3:	Certified farms are more likely to test irrigation water.
HQ4:	Certified farms are more likely to calculate fertilizer application rates.
HQ5:	Certified farms are more likely to test manure, compost, and other inputs.
HQ6:	Higher educated operators are more likely to have a soil testing plan.
HQ7:	Higher educated operators are more likely to use soil testing results to adjust fertilizer application.
HQ8:	Higher educated operators are more likely to test irrigation water.
HQ9:	Higher educated operators are more likely to calculate fertilizer application rates.
HQ10:	Higher educated operators are more likely to test manure, compost, and other inputs.
HQ11:	Higher profit operations are more likely to have a soil testing plan.
HQ12:	Higher profit operations are more likely to use soil testing results to adjust fertilizer application.
HQ13:	Higher profit operations are more likely to test irrigation water.
HQ14:	Higher profit operations are more likely to calculate fertilizer application rates.
HQ15:	Higher profit operations are more likely to test manure, compost, and other inputs.
HQ16:	Higher profit operations are more likely to be certified.
HQ17:	Higher educated operators are more likely to be certified.

In cases where a hypothesis involved the comparison of one quantitative variable across categories of a qualitative variable, either the t-test or a one-way analysis of variance (ANOVA) was employed. Both of these tests are used to determine if there is a statistically significant difference between the means of two (t-test) or more (ANOVA) groups. For the tests completed up to this point, only the t-test was used due to the low number of responses; however, the ANOVA test will be useful in the continuation of this study. For example, to test if there is a difference in the mean phosphorus concentration (ppm) between the populations of farmers that do and do not test their irrigation water, the code would follow the format:

```
data$Phosphorus ← as. numeric(data$Phosphorus)
data$IrrigationWaterTesting ← as.factor(data$IrrigationWaterTesting)
t.test(data$Phosphorus~data$IrrigationWaterTesting)
boxplot(data$Phosphorus~data$IrrigationWaterTesting)
```

The “boxplot” function produces Figure 10.

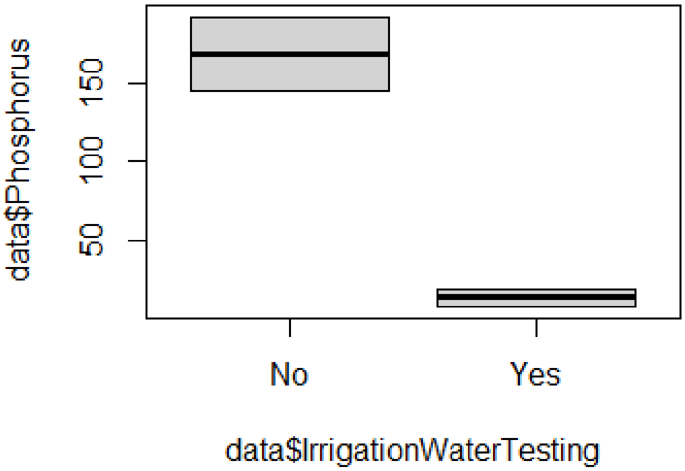

Figure 10. Boxplot Example

Again, using either test depending on the conditions tested, the *p*-value was determined for the test based on the associated test statistic. This *p*-value was used to either accept or reject the null hypothesis. If the *p*-value is less than 0.05, the null hypothesis is rejected. The null and alternative hypotheses for this test are as follows:

$$H_0: \mu_1 = \mu_2$$

$$H_1: \mu_1 \neq \mu_2$$

The null hypothesis is when the means of the samples are not significantly different, and the alternative hypothesis is when the means are significantly different. If the null hypothesis is rejected, the box plot may be used to specify the difference between the means. For this example, the *p*-value was 0.082, therefore rejecting the null hypothesis and concluding that the observed sample means were not statistically different. The hypotheses tested using the t-test are shown in Table 5.

Table 5. T-Test Hypotheses

HQ1:	Certified farms are more likely to have appropriate nutrient levels.
HQ2:	Farms that have a soil testing plan are more likely to have appropriate nutrient levels.
HQ3:	Farms that use soil testing results to adjust fertilizer application are more likely to have appropriate nutrient levels.
HQ4:	Farms that test irrigation water are more likely to have appropriate nutrient levels.
HQ5:	Farms that calculate fertilizer application rates are more likely to have appropriate nutrient levels.
HQ6:	Farms that test manure, compost, and other inputs are more likely to have appropriate nutrient levels.
HQ7:	Higher educated operators are more likely to have appropriate nutrient levels.
HQ8:	Higher profit operations are more likely to have appropriate nutrient levels.

CHAPTER 4

RESULTS

General Practices

The survey responses alone provide great insight into current organic farming practices. Determining the proper application rates for nitrogen and phosphorus is key information and is very telling of a farmer's knowledge and experience. When asked how application rates were determined, farmers' answers varied greatly. Four of the 18 farmers that answered this question relied solely on intuition. 10 of the farmers relied on one of or a combination of the following: soil tests, plant tests, and calculations from a local extension, crop advisor, or other trusted source (Figure 11).

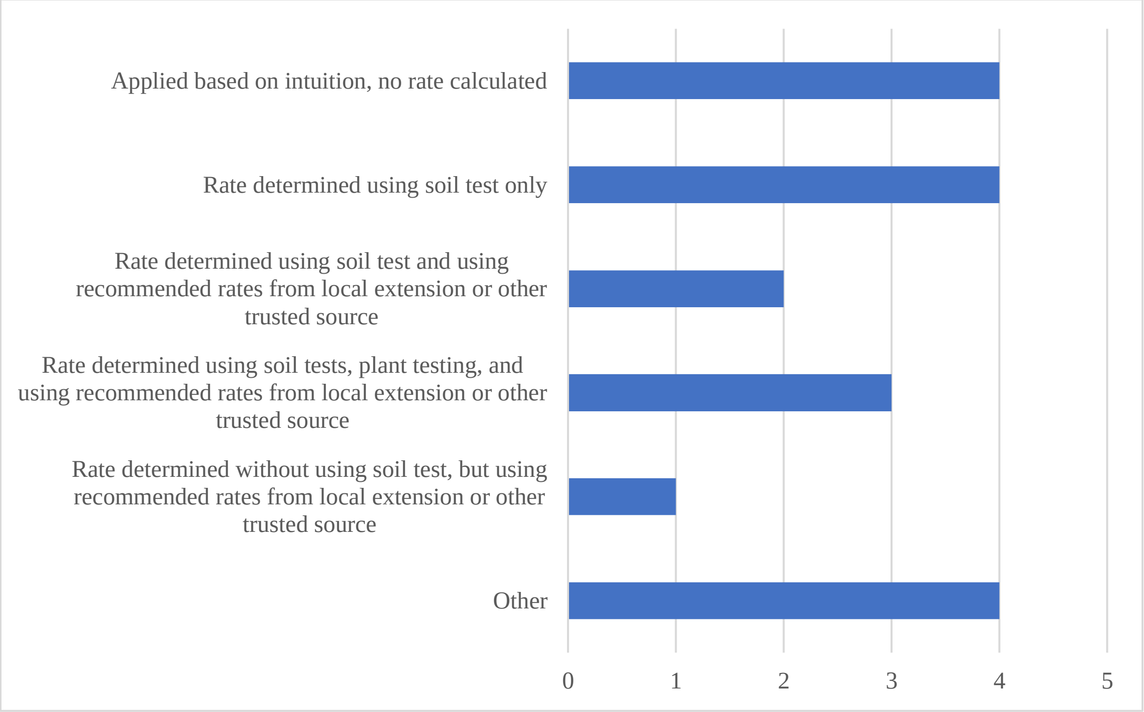

Figure 11. Methods used to determine fertilizer application rate

Looking at the specifics, nine farms do have a soil testing plan or procedure while seven do not. Of those nine farmers, only six use soil samples to adjust the fertilizer plan. Of the 12 farmers that apply compost and manure, only two test these fertilizers for nutrient composition and use this data to adjust fertilizer application. Similarly, of the 13 farms that irrigate, only seven farmers test the irrigation water nutrient composition, and of these seven farms, only four farmers indicated that these values impact fertilizer application rates. A summary of these factors and if they affect fertilizer application rates are shown in Figure 12.

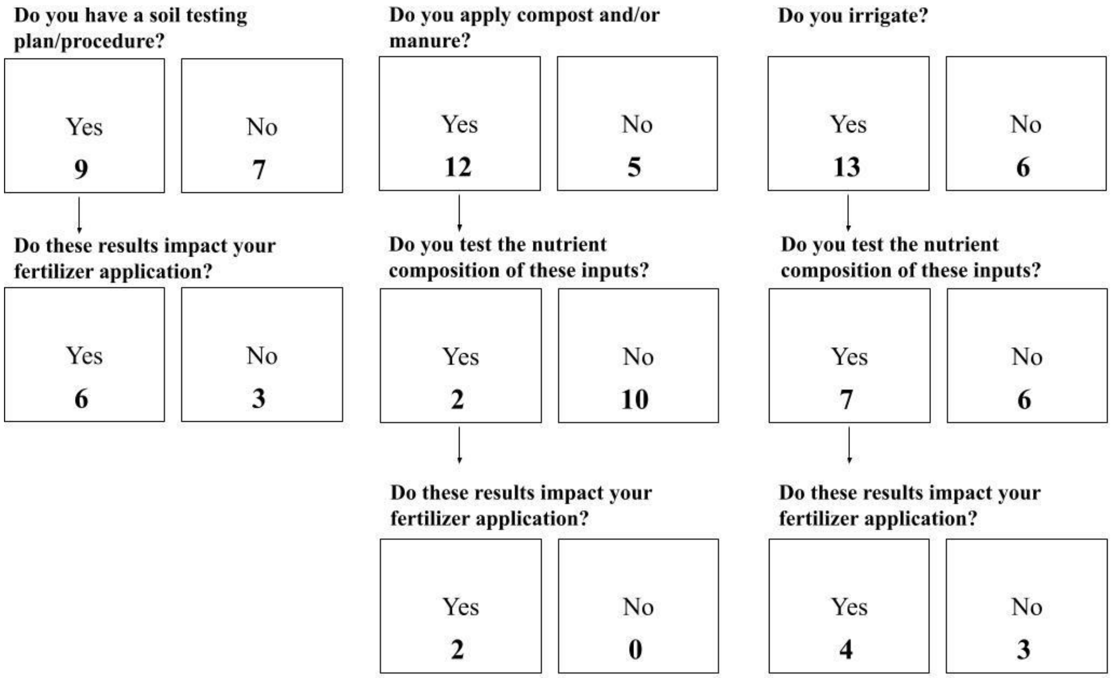

Figure 12. Relationships between various nutrient management decisions

Because farmers are indicating that they soil test, ensuring that they use appropriate sampling methods is key to assessing how accurate their results are. Ideally, farmers would test soil before each cropping season and take multiple samples per field. The sampling methods of the farmers surveyed are shown in Figure 13 and 14. Figure 13 describes how often operators are sampling which fields, while Figure 14 indicates how many samples per field are being taken. Only 3 farmers sampled each field before each crop; however, all farms that sampled took more than one sample per field.

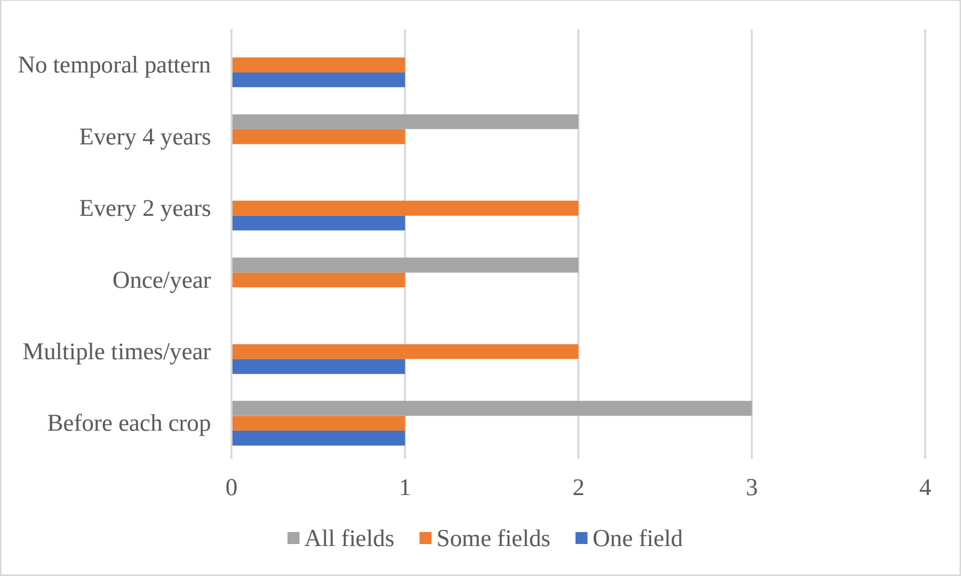

Figure 13. Frequency of soil testing

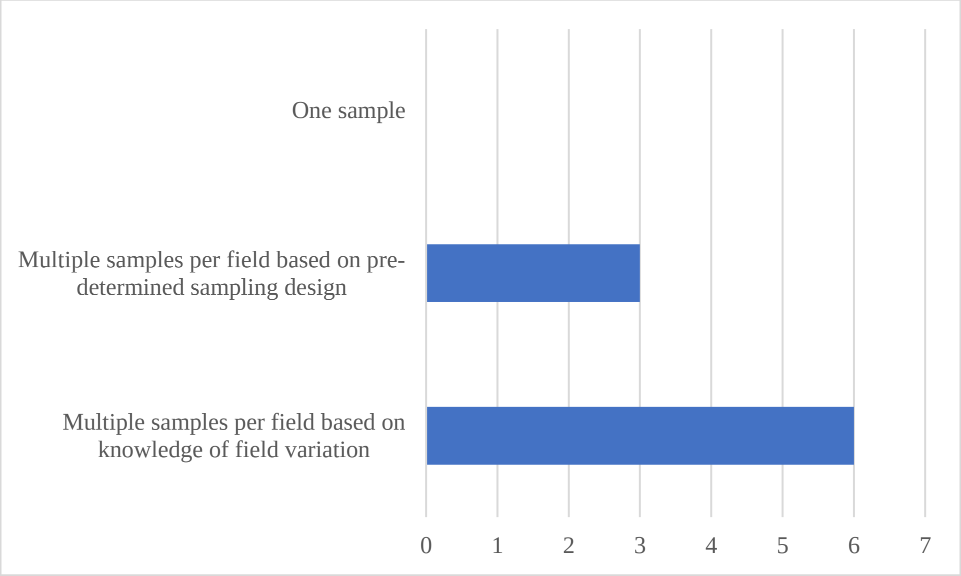

Figure 14. Replicates taken during soil testing

For the purpose of this study, it was important to see how organic regulations impacted the availability of certain nutrients. Figure 15 shows how the farmers perceived the availability of nitrogen and phosphorus fertilizers on a range from "extremely inadequate" to "extremely adequate." While these results show nutrient availability is relatively adequate, it is concerning that not many farmers reported an inadequacy of nitrogen as expected. This is indicating a gap in information either in the operator's awareness of the issue, or how well the operator's practices and experiences are understood through the survey.

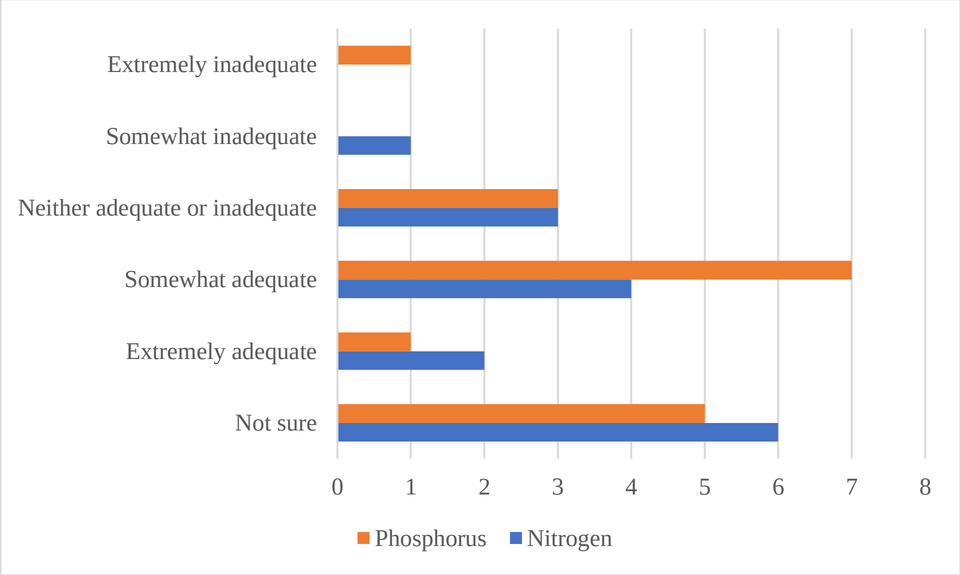

Figure 15. Perceived availability of organic fertilizer options for nitrogen and phosphorus

Another aspect of organic farming management is irrigation practices. Depending on the irrigation source, the frequency of irrigation, and other factors, this can directly affect how nutrients are transported and maintained in the soil. The irrigation source for most farms was groundwater from wells (Figure 16). No farms used city water and only six farms used surface water. The method of irrigation was very distributed, especially because farmers may utilize more than one irrigation method.

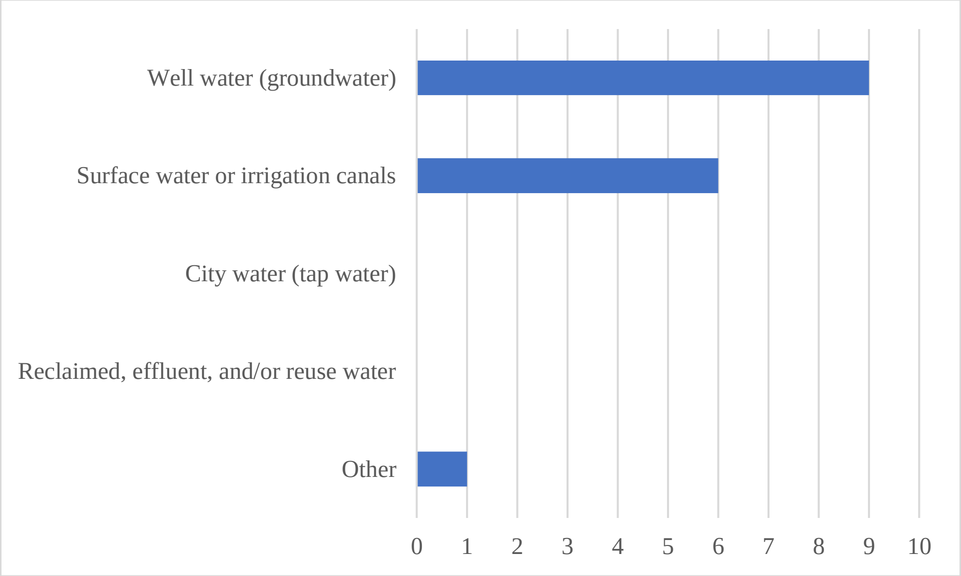

Figure 16. Irrigation water source

The frequency of irrigation is also very important, and results varied widely, but the majority of farmers relied on a season-dependent set schedule (Figure 17). It is interesting to note the difference in the number of farmers using a set schedule versus the farmers using field sensors to determine when the soil is dry. Depending on the accuracy and validity behind determining the set schedule, it is likely that the field sensors would be a better predictor of when irrigation is needed.

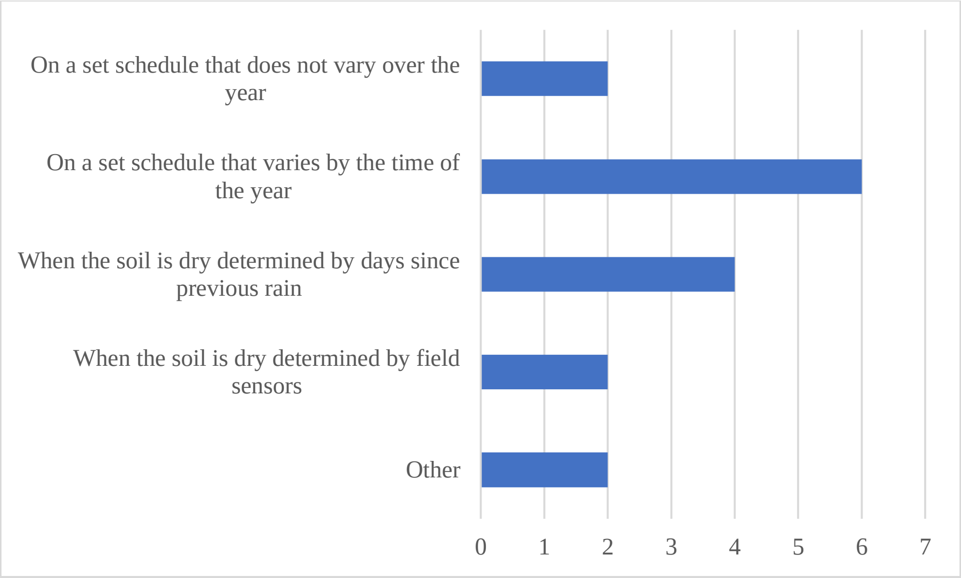

Figure 17. Irrigation Timing

Investigation of irrigation methods is important in understanding how nutrients and other matter might be transported. Figure 18 shows that of the farms that irrigate, the majority of them rely on sprinklers and drip irrigation.

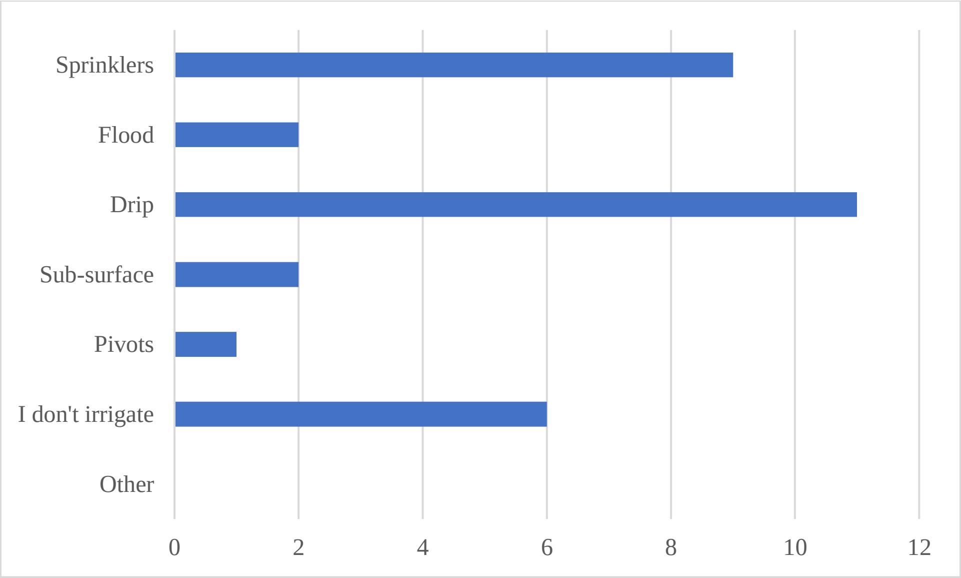

Figure 18. Irrigation Method

Finally, some miscellaneous practices that may impact nutrient availability of an operation were presented to the farmers. These practices are shown in Table 6 with the number of farmers that did and did not use the practice. Incorporating (e.g., tilling) in broadcast fertilizers can help prevent surface losses but disturbing the soil itself can also release nutrients. 10 of 16 respondents indicated they incorporated their nutrients. Similarly, injecting manures below the soil surface can prevent subsequent runoff, yet only two of 16 farmers were able to inject their manure. Interestingly, 5 of 16 farmers indicated they were unable to avoid application of fertilizers in the winter or before rain which can also lead to runoff of nutrients– another example of a non-source practice that impacts sustainability.

Table 6. Additional practices that influence sustainable nutrient management

Practice	**Yes**	**No**
Incorporation of organic fertilizers after application	10	6
Injection of manures into subsurface	2	14
Application of organic fertilizers to growing crops	10	6
Avoid application of organic fertilizers in winter or before rain	11	5
Monitor yields to adjust applications	11	5

In addition to the physical practices, understanding where farmers and operators gather their information is also important in being able to develop communication products for future work. Table 7 shows where operators receive information about specific management practices. The “total” on the right is meant to show the frequency of certain sources. This frequency shows that other farmers are the most frequent source of information, while family members/partners/friends and extension agents and specialists are tied for second most frequent.

Table 7. Information Sources

Source	**What crops to plant**	**The best tillage system**	**Determining yield goals**	**Fertilizer application rates**	**Manure application rates**	**Total**
Other farmers	3	6	5	0	5	19
Family, partners, or friends	4	1	3	2	2	12
Consultants	0	1	1	4	1	7
Extension agents and specialists	5	1	0	4	2	12
NRCS* or SWCD**	1	1	2	1	0	5
Workshops/ Courses	0	1	0	2	0	3
Other	4	6	7	3	6	26

*National Resource Conservation Service
**Soil and Water Conservation District

Soil Testing

Table 8 shows the soil test results for the six farms that sent in soil samples at the time of this thesis (April 2022). This table shows the participant ID to keep their information confidential, as well as the nitrogen and phosphorus application rates. The nitrate and phosphate levels are then shown in parts per million (ppm) along with their corresponding qualitative levels (low, medium, high, and very high). Finally, the nitrogen to phosphorus ratio (N:P) is shown. The nutrients are generally higher than recommended. It was unexpected for nitrogen levels to be this high considering the prevalent nitrogen limitation issue. Despite this, the N:P is still well below 15, indicating that nitrogen is limited. This can impact the long-term sustainability of the farm by reducing yields. Off-farm losses of phosphorus are likely increased in these systems as well potentially influencing downstream eutrophication problems.

Table 8. Soil Testing Results

Participant ID	**Nitrogen Application (lb/ac)**	**Phosphorus Application (lb/ac)**	**NO3-N ppm**	**N Level**	**PO4-P ppm**	**P Level**	**N:P**
OF2	Unsure*	Unsure*	11	Medium	19	Medium	0.58
OF7	Unsure**	Unsure**	7.6	Low	8	Low	0.95
OF11	Unsure**	Unsure**	235	Very High	192	Very High	1.22
OF14	30	5	29	High	145	Very High	0.20
OF17	Unsure*	Unsure*	30	High	12	Medium	2.50
OF19	200	150	85.91	Very High	59.87	Very High	1.48

Low (0-9.9): high probability that applying nutrient will elicit a growth response
Medium (10-25.9): moderate probability of plant growth from application
High (16-50.9): little or no response expected from application of this nutrient
Very High (51+): adding the nutrient may reduce growth or cause imbalance

*Too many fields with variable rates
**Does not keep track of this value

N limited: N:P < 14
Ideal: N:P = 15
P limited: N:P > 16

Table 9 shows the average values for these soil results. Both nitrogen and phosphorus are "very high" and the N:P is well below the ideal of 15.

Table 9. Average Soil Results

NO3-N ppm	**N Level**	**PO4-P ppm**	**P Level**	**N:P**
66.42	Very High	72.64	Very High	1.16

Statistical Testing

Overall, due to a small sample size (n=19), most tests completed were not statistically significant. In fact, no tested contingency tables of categorical variables could use the Chi-squared test due to low cell frequencies so only Fisher's Exact test was used. Some hypotheses had low *p*-values that were close to the significance level, and with a larger sample size, may result in significant relationships. For example, when testing whether or not farm profit and testing of manures were dependent, the *p*-value of 0.154 is low, yet not reaching our significance level. Many hypotheses were tested exploring relationships between nutrient management practices and farmer demographics and nutrient levels in the soils using t-tests. Only six soil sample results were returned at the time of the writing of this work, so the results are similar with no significant test results, but some approaching significance. For example, when testing if farmers that tested their irrigation water for nutrients had lower phosphorus levels, the derived *p*-value was 0.082 一 the lowest value this study found. Table 10 shows a description of the variables tested through this statistical analysis.

Table 10. Variable Descriptions

Variable	**Definition**	**Categories**
Certification Status	Is the operation certified?	Certified/Not Certified
Soil Testing Plan	Does the operation have a soil testing plan?	Yes/No
Use of Soil Results	How are the soil test results utilized?	Just to monitor/To adjust fertilizer application
Test Irrigation Water	Does this operation test the nutrient composition of irrigation water?	Yes/No
Application Rate Determination	How are fertilizer application rates determined?	Calculated/Not Calculated
Rural/Suburban	Is this operation located in a rural or suburban area?	Rural/Suburban
Test Unknown N:P	Does this operation test the nutrient composition of manure, compost, etc.?	Yes/No
Profit	How much does this operation profit annually?	<$100,000 or >$100,000
Education	What is the educational background of the operator?	Personal experience/Professional education
Phosphorus	Phosphorus level of soil sample	ppm
Nitrogen	Nitrogen level of soil sample	ppm

Table 11 shows a summary of the Chi-squared tests and their results. Variables 1 and 2 are the variables tested for significance. “dF” indicates the degrees of freedom of the test, the *“p*-value” indicates the *p*-value calculated, and the “conclusion” indicates whether the null hypothesis was rejected or not.

Table 11. Chi-Squared Results

Variable 1	**Variable 2**	**df**	**p-value**	**Conclusion**
Certification Status	Soil Testing Plan	1	0.569	H_0
Certification Status	Use of Soil Results	1	1.00	H_0
Certification Status	Test Irrigation Water	1	0.455	H_0
Certification Status	Application Rate Determination	1	0.577	H_0
Certification Status	Rural/Suburban	1	0.314	H_0
Soil Testing Plan	Test Irrigation Water	1	1.00	H_0
Test Unknown N:P	Test Irrigation Water	1	1.00	H_0
Test Unknown N:P	Soil Testing Plan	1	1.00	H_0
Soil Testing Plan	Rural/Suburban	1	1.00	H_0
Test Irrigation Water	Rural/Suburban	1	1.00	H_0
Certification Status	Test Unknown N:P	1	1.00	H_0
Education	Certification Status	1	0.203	H_0
Education	Soil Plan	1	1.00	H_0
Education	Application Rate Determination	1	1.00	H_0
Education	Use of Soil Results	1	0.400	H_0
Education	Test Irrigation Water	1	1.00	H_0
Education	Rural/Suburban	1	1.00	H_0
Education	Test Unknown N:P	1	0.491	H_0
Profit	Certification Status	1	1.00	H_0
Profit	Use of Soil Results	1	0.464	H_0
Profit	Test Irrigation Water	1	1.00	H_0
Profit	Application Rate Determination	1	1.00	H_0
Profit	Soil Testing Plan	1	0.569	H_0
Profit	Rural/Suburban	1	1.00	H_0
Profit	Test Unknown N:P	1	0.154	H_0

H_0: The two variables are independent
H_1: The two variables are dependent

Table 12 shows the summary of results for the t-tests conducted. Similar to Table 11, this table includes data for the degrees of freedom, the *p*-value, and the conclusion of the test; however, this table also shows the "*t* value," which represents the variation of the sample. It should be noted that the nutrient levels depending on certification status and how operators use their soil testing results was intended to be tested, but because of the even more limited sample size, there was not enough data. As this study progresses and collects more survey responses and soil results, these tests will be revisited.

Table 12. T-Test Results

Variable	**Nutrient**	**dF**	***t* value**	**p-value**	**Conclusion**
Soil Testing Plan	Nitrogen	1.006	0.860	0.547	H_0
Soil Testing Plan	Phosphorus	1.455	0.407	0.736	H_0
Test Irrigation Water	Nitrogen	1.001	1.191	0.445	H_0
Test Irrigation Water	Phosphorus	1.109	6.422	0.082	H_0
Application Rate Determination	Nitrogen	1.006	0.860	0.547	H_0
Application Rate Determination	Phosphorus	1.455	0.407	0.736	H_0
Profit	Nitrogen	2.088	-1.017	0.413	H_0
Profit	Phosphorus	2.375	0.024	0.983	H_0
Education	Nitrogen	1.02	0.926	0.522	H_0
Education	Phosphorus	1.001	1.104	0.469	H_0
Test Unknown N:P.	Nitrogen	2.096	1.002	0.418	H_0
Test Unknown N:P	Phosphorus	2.006	2.102	0.170	H_0

H_0: $\mu_1 = \mu_2$, *there is no significant difference between the sample means*
H_1: $\mu_1 \neq \mu_2$, *there is a significant difference between the sample means*

There was one t-test that was noticeably close to achieving a *p*-value of 0.05. This *p*-value was 0.082 when testing if there is a difference in phosphorus levels (ppm) between operators that do or do not test their irrigation water. A box plot was made to analyze the emerging significance (Figure 19). The line in each box depicts the sample mean and either end of the box depicts the minimum and maximum values.

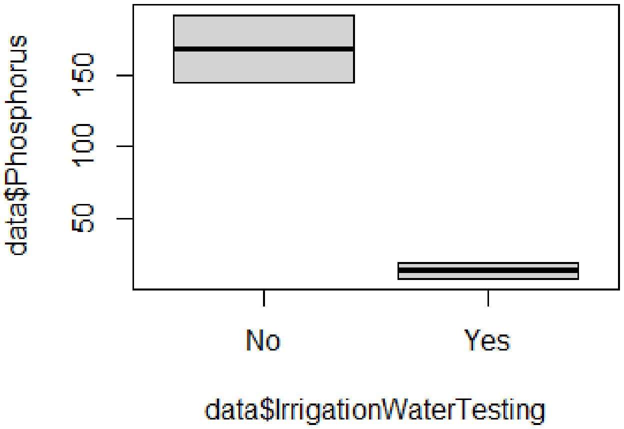

Figure 19. Phosphorus Levels v Irrigation Testing

A summary of the mean, minimum, and maximum values of the Figure 20 are displayed in Table 13.

Table 13. Phosphorus Levels v Irrigation Testing Summary

	Irrigation Water Not Tested	Irrigation Water Tested
Mean (PO4-P ppm)	168.5	13.5
Minimum (PO4-P ppm)	145	8
Maximum (PO4-P ppm)	192	19

CHAPTER 5

DISCUSSION

Overall, the current nutrient management practices employed by organic farming operations are extremely variable, though it should be noted that the sample size was low. No clear correlation is shown between the demographics of the operations and practices, but this could likely be due to the small sample size and therefore low statistical power. More surprisingly, there is not a significant difference between the non-certified and certified organic farming practices as expected (though only three of 19 were not certified). The finding that the farms have such different practices supports the idea that organic does not necessarily mean sustainability because there is such little regulation on the practices themselves outside of what sources of fertilizers are allowed. Most organic regulation focuses on what inputs are being applied but not what quantity and frequency, or other practices that can influence outcomes. One of the key hypotheses was that farmers would not be conducting regular soil nutrient tests in order to properly calculate the necessary nutrient application rate. While more farms practiced soil testing than expected, this was only about half of them. Farmers should be testing their soils for nutrient content in order to determine appropriate fertilizer application rates (Johnston and Bruulsema 2014). It was also expected that phosphorus would more commonly be overfertilized, while nitrogen would be unfertilized and that farmers would experience a difficult time achieving the ideal nitrogen to phosphorus ratio of 15:1. Most farmers are indicating that they have not had issues achieving adequate nitrogen and phosphorus fertilizers. This was not expected as nitrogen is extremely limited; however, this does say something about the experience of the farmers surveys. If farmers are not aware of this issue, they may not realize the importance of maintaining a proper nitrogen to phosphorus ratio. Generally, the nitrogen content of the soil samples was much higher than expected since nitrogen is so limited in organic fertilizers. This shifts the attention to look at what organic farmers are doing to achieve such high nitrogen levels despite the limitation of nitrogen. More research should be done as to understand how these farmers are achieving these high nitrogen levels.

Based on the current results, it has been observed that these operations may rely more heavily on cheaper fertilizer options such as manure or compost where the nutrient content is not known. If these farms also do not soil test, it is possible that they are overfertilizing by applying whatever inputs become available to them. Relationships such as this would be worth researching further. Similarly, as more results are gathered, it would be important to evaluate what the operations with the most ideal N:P ratios are practicing and what specifically might allow operations to attain that ratio. The overarching hypothesis of this study was that farmers would not be able to effectively apply nutrients in the favor of both organic and sustainable practices. While more soil testing and survey responses would be ideal– based on the current responses it does appear that the misconception that organic and sustainable practices are one in the same is prevalent among this sample. When asked why participants were drawn to organic practices they stated, “to improve soil health and biodiversity,” “for health and environmental sustainability,” for “long term sustainability,” and because “it is the most resilient system.” Because of this, a clear barrier to achieving environmentally sustainable practices is present. The majority of the responses indicate a desire to promote environmental and human health as their motivation for organic farming. The farmers indicated they prefer organic because it creates “nutrient rich” crops that are better for human health. They believe it is more sustainable than conventional farming, especially in preserving soil health and surrounding water sources. One participant that encapsulated all of these values wrote that they practice organic farming over conventional farming “to improve soil health and biodiversity, enhance habitat for beneficials and wildlife, reduce dependence on purchased inputs, produce healthier foods, and to provide a healthier place for people, animals and plants to live and visit.” Without accurate information on this key aspect of soil and environmental health, these farmers may not know about this potential sustainability barrier. Three participants, however, indicated that one of their reasons for organic farming was because of buyer demand and the high marketing prices. A few participants wrote that they simply do not want the trouble of adding pesticides, herbicides, and fertilizers, while one of these responses indicated this was due to avoiding contamination of medicinal herbs. This data also brings to light new possible correlations to be investigated. One participant indicated that they chose organic because of the profit margin. It would be beneficial to look into the profit margin and how it influences the increase in organic farming and subsequent practices. Examining the sustainability of organic practices brings up the issue of the trade-offs that come with fertilizer sourcing. For instance, retrieving and spreading these organic nutrients can be energy intensive, however the implications of eutrophication have great impacts on greenhouse gas emissions (University of Minnesota 2019). How this compares to energy-intensive inorganic fertilizers still needs to be assessed.

Limitations and Future Research

The limitations of this study are largely due to the small sample size and lack of diversity. Limitations of soil samples could be due to a lack of interest in the survey pool, or because most of the locations surveyed were still dealing with winter weather during the time of this study and might not have been physically able to retrieve a soil sample. Especially with the severe lack of non-certified farmers, this project may consider opening up the audience to more conventional audiences. This could even open possibilities for new perspectives and interesting insight and comparisons between the two farming standards. Although the online survey was necessary in order to reach a wide audience in a short amount of time, it attempts to analyze complex ideas and information into a simplified form that can be easily compared to other samples for the sake of statistical analysis. Furthermore, this method relies heavily on the accuracy and truthfulness of the participants and their answers. Future work will involve continued recruitment in order to achieve a larger and more diverse sample. More soil testing will be completed in order to accurately compare survey results with the soil quality of the farm. With the increase in sample size of both the participants and soil samples, statistically sound correlations may become more apparent.

CHAPTER 6

CONCLUSION

The current results of this study show that while there is a clear desire to promote environmentally sustainable practices, there is also a clear misconception among organic farmers that organic practices are automatically sustainable. Even the operations under organic certification regulations are extremely variable and show little effort implementing known best nutrient management practices outside avoiding the application of inorganic fertilizers and pesticides. There is no regulation on application rates or how an operation might determine these proper rates and other key nutrient management practices. There is an evident issue surrounding improper fertilization within organic farming based on the observations of this study. To remedy this, educational resources as well as the programs to allow cheap nutrient testing should become more easily accessible to organic farmers. As the interest in organic farming increases, it becomes increasingly important to employ feasible and environmentally sustainable nutrient management practices in order to ensure its longevity. To do this, a clear emphasis must be placed on the education and awareness of the duality of organic and sustainable ideals. This study only explored one aspect of sustainability, but there may be more worth evaluating. Agriculture and environmental sustainability are already complex ideas on their own, and when combined, create an incredibly complex system, therefore, the rules to achieving an environmentally sustainable agricultural operation must reflect a complex system.

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APPENDIX A

SURVEY QUESTIONS

Q1 My name is Emma Bonham, and I am a graduate student in the Ira A. Fulton School of Engineering under the direction of Dr. Alaina Zanin and Dr. Rebecca Muenich. This study is in partnership with the United States Department of Agriculture (Dr. Clinton Williams). I am conducting a research study to understand how nutrient management is impacted by organic farming practices.

Your participation in this research will involve an online survey (through Qualtrics) evaluating your organic farm management and practices. The survey will take approximately 15-20 minutes to complete. The first 100 respondents will be offered a free soil test for their participation. We anticipate to receive 200-500 responses. You have the right to not answer any question as well as the right to withdraw at any time. You will be compensated with the chance to win free lab tests and results for your farm if you choose to participate. Participation is voluntary and there will be no penalty for withdrawal. You must be 18 or older to participate. There are no anticipated risks to participating in the study and benefits include the opportunity to receive a free soil test.

Your responses will be confidential and not associated with your identifiable information. The data will be stored on ASU’s secure server. We will not retain identifying information, except for your name and contact information which will be used for collecting soils data if you choose. De-identified data collected as a part of the current study will be shared with other investigators for future research purposes. This information will be destroyed 6 months after you complete the survey. The results of this study and excerpts from your responses may be used in reports, presentations, or publications, but your name or other identifying information will not be used.

If you have any questions regarding the survey or study, please contact the research team: Dr. Alaina Zanin at alaina.zanin@asu.edu, Dr. Rebecca Muenich at Rebecca.Muenich@asu.edu, or Emma Bonham at ebonham@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

By continuing on to the survey, you consent to participate in the study.

Q2 Are you 18 years or older?

○ Yes

○ No

Q3 Do you identify as an organic farmer?

○ Yes

○ No

Q4 Are you the owner/operator of the operation?

○ Yes

○ No

Q5 Do you currently produce crops on your farm?

○ Yes

○ No

Q6 Are you interested in receiving a free soil test if you are one of the first 100 respondents?

○ Yes

○ No

Q7 If selected for a free soil test, are you willing to collect and mail your sample if we mail you instructions and a return mailing?

○ Yes

○ No

Q8 Thank you for your participation. Please provide your contact information below in the case that you receive the free soil test. Your information will only be used to mail you the sample kit if you are selected, otherwise it will be deleted.

○ Name (Last, First) ____

○ Email ____

Q9 By signing below you consent to being entered for a chance to win free soil testing. You are agreeing to collect and send a soil sample by mail to be tested.

____

Q10 What state is the majority of your operation located?

▼ Alaska ... Wyoming

Q11 What city (or nearest city) is the majority of your operation located?

▼ Alexander City ... Worland

Q12 Which of the following best describes how you would define the location of your farm?

○ Rural

○ Urban

○ Suburban/Peri-Urban

Q13 Which of the following best describes your operation

☐ I currently operate a commercial farm

☐ I currently operate a non-commercial farm (e.g., community farm, subsistence farm)

☐ I own all of the land that I farm

☐ I rent all of the land that I farm

☐ I rent my land to someone else who farms it

☐ Other: ____

Q14 In what year did you or the current manager of this operation first grow or raise any agricultural products?

▼ 2021 ... 1900

Q15 Approximately, what was your operation's gross sales over the last year?

○ Non-profit farm

○ $1-$25,000

○ $25,001-$100,000

○ $100,001-$500,000

○ More than $500,000

Q16 Is the farm your main source of household income?

○ Yes, main source of income

○ No, supplemental income

Q17 Approximately, how much money did you spend on organic fertilizers in your most recent cropping season (total)?

○ $ ____

Q18 Approximately, how much money did you spend on nutrient management (not including fertilizer costs) in your most recent cropping season?

○ $ ____

Q19 Approximately, how many different crops has your operation produced in the last 3 years?

○ 1

○ 2

○ 3

○ 4

○ 5 or more

Q20 What crops do you grow now?

☐ Horticultural crops (fruits, nuts, vegetables, herbs, and spices)

☐ Field crops (cereals, oilseed, pulses, and forage)

☐ Ornamental horticulture/landscaping

☐ Other ____

Q21 Approximately, how many acres is your operation?

○ 0 - 0.9 acres

○ 1 - 4.9 acres

○ 5 - 9.9 acres

○ 10 - 19.9 acres

○ 20 - 49.9 acres

○ 50 acres or more

Q22 What is your Organic Certification status? To review the USDA's Organic Regulations Click Here

○ Certified

○ Not Certified

Q23 What kind of production do you practice?

○ USDA Certified Organic Production

○ Organic production by own definition

○ Certified regenerative agriculture

○ Indigenous farming

○ Conventional farming (use of synthetic chemicals)

Q24 In what year did your operation first become certified?

▼ 2021 ... 1900

Q25 What is your challenge to transitioning to certified organic farming?

☐ Financial

☐ Time and effort to become certified

☐ Lack of information on how to become certified

☐ I did not know about the program

☐ Other ____

Q26 If not USDA certified organic producer, would you transition to organic production in the future?

○ Yes

○ No

Q27 Over the next 5 years, does this operation plan to:

○ Increase organic agricultural production

○ Maintain current levels of organic agricultural production

○ Decrease organic agricultural production

○ Discontinue organic agricultural production

○ Discontinue all agricultural production

○ ⊗ Don't know

Q28 Which of the sources of information (listed below) do you find most useful when making a decision for?

What crops will be planted on the land you operate	▼ Other farmers ... Other
The best tillage system	▼ Other farmers ... Other
Determining the yield goal for your crops	▼ Other farmers ... Other
Deciding on nutrient (NPK) rates for your crops	▼ Other farmers ... Other
Figuring out the best rates and locations for distributing manure	▼ Other farmers ... Other

Q29 Are there any crops that are more difficult to support using only organic farming methods?

○ Yes - Which ones? ____

○ No

Q30 Do you continue to grow these crops?

☐ Yes - Which ones? ____

☐ No - Which ones? ____

Q31 What type of irrigation system do you use in your operation?

☐ Sprinklers

☐ Open flood

☐ Sub-surface

☐ Drip

☐ Pivots

☐ ⊗I don't irrigate

☐ Other: ____

Q32 How do you decide when to irrigate?

☐ On a set schedule that doesn't vary over the year (e.g., daily, weekly)

☐ On a set schedule that varies by time of the year (e.g., daily in summer, weekly in winter)

☐ When the soil is dry as determined by days since a previous rain

☐ When the soil is dry determined by field sensors

☐ Other: ____

Q33 What is your source of irrigation water?

☐ Well water (groundwater)

☐ City water (tap water)

☐ Surface water or surface water irrigation canals

☐ Reclaimed, effluent, and/or reuse water

☐ Other: ____

Q34 Do you test this water for its nutrient composition?

○ Yes

○ No

Q35 Do the results influence your fertilizer application and/or calculations?

○ Yes

○ No

Q36 Which of the following best describes your fertilizer applications?

○ Applied based on intuition; no rate calculated

○ Rate determined using soil test only

○ Rate determined using soil test and calculations from local extension, crop advisor, or other trusted source

○ Rate determined using soil tests, plant testing, and calculations from local extension, crop advisor or other trusted source

○ Rate determined without using soil test, but using recommended rates from local extension, or other trusted source

○ Other: ____

Q37 What are your average application rates of nutrients across your farm?

☐ Nitrogen (lbs actual N/ac)

____

☐ Phosphorus (lbs actual P/ac)

____

☐ ⊗Unsure - too many fields with variable rates to determine

☐ ⊗Unsure - I don't keep track of this value

☐ ⊗Unsure - I have never determined this rate

Q38 Were adequate organic fertilizers available as needed for this operation in the last 3 years?

	Extremely inadequate	Somewhat inadequate	Neither adequate nor inadequate	Somewhat adequate	Extremely adequate	Not sure
Nitrogen	○	○	○	○	○	○
Phosphorus	○	○	○	○	○	○

Q39 How did you determine the adequacy/inadequacy of nutrients for your crops?

☐ Soil testing

☐ Plant health

☐ Intuition

☐ Other: ____

Q40 Do you use raw manure? If so, what kind?

○ No manure used

○ Animal manure

○ Animal products

○ Green and animal manure/products

Q41 Do you use compost? If so, what kind of sources make up your compost?

☐ No compost used

☐ Animal manure

☐ Animal products

☐ Food waste

☐ Green waste

☐ Crop residues

☐ Other: ____

Q42 Do you use treated animal products? If so, what kind?

☐ No treated animal products

☐ Treated animal manure (e.g., digested, recovered)

☐ Bone meal

☐ Blood meal

☐ Feather meal

☐ Fish emulsion

☐ Seaweed emulsion

☐ Green and animal manure/products

Q43 Do you test manures, composts, or other organic fertilizers if their nutrient concentrations are not known?

○ Yes

○ No

Q44 How do you determine your manure or compost application rate?

☐ Soil test analysis

☐ Manure analysis

☐ Manure nutrient table values

☐ Spreader capacity

☐ Paid crop consultant

☐ Same amount each time

☐ None of these are used

☐ Other: ____

Q45 Do you reduce your fertilizer or manure rate to account for nutrients from any of the following sources?

☐ Previous manure application

☐ Previous legume crop

☐ Irrigation water nitrate

☐ No

☐ Determined by crop consultant

☐ Other: ____

☐ Not applicable

Q46 How often do you use the following practices?

	Always	Often	Sometimes	Never
Incorporation of organic fertilizers after application	○	○	○	○
Injection of manures into subsurface	○	○	○	○
Application of organic fertilizers to growing crops	○	○	○	○
Avoid application of organic fertilizers in winter or before rain	○	○	○	○
Monitor yields to adjust applications	○	○	○	○

Q47 Do you have a soil testing program, plan, and/or procedure?

○ Yes

○ No

Q48 Which best describes your space and time approach to sampling your fields (please select one response for each row). For example, if you test some of your fields every year, then select the row "Once/year" and column "some fields."

	All fields	Some fields	One field
Before each crop	○	○	○
Multiple times/year	○	○	○
Once/year	○	○	○
Every 2 years	○	○	○
Every 4 years	○	○	○
No temporal pattern to when I test	○	○	○

Q49 When you sample a field for soil testing purposes, do you:

○ Collect one sample

○ Multiple samples per field (based on knowledge of field variation)

○ Multiple samples per field (based on a pre-determined sampling design)

Q50 How do you use these soil test results?

○ To adjust the fertilizer plan

○ Just to monitor

○ Other: ____

Q51 Would you be willing to share the results if you have them?

○ Yes

○ No

Q52 If you would be willing to share these results, please enter your contact information below and we will follow up with you to request your results.

○ Name (Last, First) ____

○ Email ____

Q53 Is there anything we didn't cover that you would like to share about your nutrient management practices?

○ Yes ____

○ No

Q54 Why did you decide to practice organic farming over conventional farming? (200 word limit)

____

Q55 How many years of total farming experience do you have?

	0 - 1 year	1 - 2 years	2 - 5 years	6-10 years	11-20 years	21-40 years	41 years or more
Conventional farming	○	○	○	○	○	○	○
Organic farming	○	○	○	○	○	○	○

Q56 What other previous experience related to organic farming do you have?

☐ B.S., M.S., or PhD Degree in agriculture or agriculture-related field

☐ B.A. or associated degree in agriculture or agriculture-related field

☐ Grew up or have lived on a farm

☐ Other: ____

Q57 How would you describe the advantages and/or disadvantages of organic farming? (200 word limit)

____

Q58 How does your location influence your farming practices? (Climate, topography, input availability, etc.) (200 word limit)

____

Thank you for your time spent taking the survey. Your response has been recorded.

If you indicated interest in having your soil tested or sharing existing soil tests, we will follow up with you soon via your provided email address.

APPENDIX B

SAMPLING INSTRUCTIONS

Sample Collection Instructions

Materials:

1. Spade, soil auger, or other soil collection tool
2. Plastic Bag (provided)
3. Sample Details Form (provided)
4. Return Box (provided)

Choosing your sample location:

1. Since we will be collecting one sample per participant, you should choose an area that you feel is representative of your current nutrient management practices**.** This means that you should choose a field or area in which you use your standard fertilization practices.
2. Avoid taking a sample from the very edge of a field or planting bed.
3. Avoid areas that are extremely wet unless you plan to dry the sample.

Sample collection and return:

1. Make sure your spade, soil auger, or other collection tool is clean before sampling to avoid cross contamination. Simply rinsing with water to remove any previous soil and drying should be sufficient.
2. Using a spade, soil auger, or other similar tool, collect a soil sample with as much depth range as possible (about 1 to 6 inches deep). It is important to get multiple layers of soil in your sample as the nutrient levels vary throughout. By collecting a wider range of layers, we get a sample that is better representative of your soil.

   ○ Try to avoid extremely wet soil conditions. If the soil is wet, spread the sample out on paper towels or newspaper and allow to dry before packaging. Do not attempt to heat the sample.
3. Aim to collect about 1 to 2 pounds of **DRY** soil into the provided plastic bag for laboratory testing.
4. If you would like to use these results for soil management purposes, please fill out the ***Soil Details Form*** and return it with your sample.
5. Seal the ***soil sample*** and ***Soil Details Form*** in the provided **box** for return shipping.
6. Take your package to your local post office as soon as possible. Doing this sooner than later helps to provide you with the most accurate lab results.

Thank you for your time and participation!

APPENDIX C

SOIL DETAILS FORM

Soil Details Form

Participation ID: _______

Date Sampled (mm/dd/yy): ____

Crop currently grown (in none, enter N/A): ____________________________________

Last crop grown (in none, enter N/A): ____________________________________

Crop to be grown (in none, enter N/A): ____________________________________

Would you like a recommendation for a specific crop?

- Yes
- No

If yes, which crop? _____________________

APPENDIX D

IRB APPROVAL

EXEMPTION GRANTED

Rebecca Muenich
SEBE: Sustainable Engineering and the Built Environment, School of
-
Rebecca.Muenich@asu.edu

Dear Rebecca Muenich:

On 1/5/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Assessment of nutrient management on organic farms in the U.S.
Investigator:	Rebecca Muenich
IRB ID:	STUDY00015071
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Email recruitment wording, Category: Recruitment Materials; • Email to list-serve consent, Category: Consent Form;• Example file to be sent with results to participants who receive soil test, Category: Technical materials/diagrams; • IRB Protocol -clean, Category: IRB Protocol; • Survey Consent - clean, Category: Consent Form;• Survey Instrument, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 12/16/2021.
In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).
If any changes are made to the study, the IRB must be notified at research.integrity@asu.edu to determine if additional reviews/approvals are required.

Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

All in-person interactions with human subjects require the completion of the ASU Daily Health Check by the ASU members prior to the interaction and the use of face coverings by researchers, research teams and research participants during the interaction. These requirements will minimize risk, protect health and support a safe research environment. These requirements apply both on- and off-campus.

The above change is effective immediately until further notice and replaces all previously published guidance. Thank you for your continued commitment to ensuring a healthy and productive ASU community.

Sincerely,

IRB Administrator

cc:
    Emma Bonham
    Alaina Zanin

APPENDIX E

IRB MODIFICATION APPROVAL

ASU Knowledge Enterprise Development

APPROVAL: MODIFICATION

Rebecca Muenich
SEBE: Sustainable Engineering and the Built Environment, School of
-
Rebecca.Muenich@asu.edu

Dear Rebecca Muenich:

On 2/4/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Modification / Update
Title:	Assessment of nutrient management on organic farms in the U.S.
Investigator:	Rebecca Muenich
IRB ID:	STUDY00015071
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• IRB Protocol - clean, Category: IRB Protocol; • Social Media Recruitment Infographic, Category: Recruitment Materials;

The IRB approved the modification.

When consent is appropriate, you must use final, watermarked versions available under the “Documents” tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

REMINDER - Effective January 12, 2022, in-person interactions with human subjects require adherence to all current policies for ASU faculty, staff, students and visitors. Up to-date information regarding ASU’s COVID-19 Management Strategy can be found here. IRB approval is related to the research activity involving human subjects, all other protocols related to COVID-19 management including face coverings, health checks, facility access, etc. are governed by current ASU policy.

Sincerely,

IRB Administrator

cc:
Emma Bonham
Alaina Zanin

APPENDIX F

SURVEY DISTRIBUTORS

1. California Certified Organic Farmers
2. EcoFarm
3. Future Harvest
4. Maine Organic Farmers and Gardeners Association
5. Midwest Organic and Sustainable Education Services
6. National Sustainable Agriculture Coalition
7. Northeast Organic Farming Association
8. Ohio Ecological Food and Farm Association
9. Organic Farmer's Association
10. Organic Trade Association
11. Pennsylvania Association for Sustainable Agriculture
12. Rodale Insititute
13. The Organic Center
14. The Organic Farming Research Foundation