PRECISION AGRICULTURE ADOPTION BY GROWERS IN SOUTH CENTRAL NEBRASKA

by

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ABSTRACT

This thesis was commissioned by Cooperative Producers, Inc. (CPI) of Hastings, Nebraska in order to better understand the preferences and uses of precision agriculture by customers within the company's trade territory. With the rapid increase of precision agriculture (hardware, software, services, etc.) it is necessary to get a better understanding of what drives growers to adopt and implement precision agriculture practices. A paper survey was sent out in CPI's monthly statements to patrons that also included instructions to be able to fill out an online survey if that was preferred. From that offering there were a total of 114 responses providing data from which several technology adoption models were estimated.

Based on prior experience with precision agriculture and the development of services offered to growers, it is hypothesized that there are three primary variables influencing a grower's decision to adopt precision agriculture. If the operation is managed by a younger grower (<40 years old), farms with a larger number of acres, and if a high percent of the operation's acres are irrigated they will be more likely to adopt precision agriculture practices. The survey results generally revealed that younger farmers, larger farm size, and a higher percentage of irrigated acres did not increase the likelihood of utilizing precision agriculture. The questions asked in the survey were designed to provide information for the development of a tool that salespeople offering precision agriculture services could use to determine if a potential customer with be inclined to adopt and utilize precision agriculture. While some of the results were contrary to expectations they do offer

insight into what type of customer adopts precision agriculture and a direction for CPI to move in order to maximize market penetration.

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ACKNOWLEDGMENTS

I first give recognition to completion of this thesis to my God through whom all things are possible and who enabled me to remain focused. My wonderful wife put up with me being away from the family and helped me through this process by helping me stay on task, and for that I thank her. My three beautiful children understood what it meant when I needed to do “homework” and behaved as any parent would want and my hope is that through this work I can show them what commitment and dedication means. Many thanks to the Master of Agribusiness faculty and staff for organizing such a great program; and especially to Dr. Allen Featherstone, Lynnette Brummett, Deborah Kohl, and Mary Bowen for helping the students through every step of the process. Finally, I would like to thank my thesis committee (Dr. Kevin Dhuyvetter, Dr. Sean Fox, and Dr. Jason Bergtold) for guiding me through this process and making sure that I complete only the highest quality work worthy of recognition from Kansas State University.

CHAPTER I: INTRODUCTION

Over the last decade, the rise of precision agriculture has paralleled the increase in computing technology. With this rise there has been a large amount of agricultural technology data that have been captured from application, field sampling, and harvest data collection. As these data are collected more easily and accurately, Cooperative Producers, Inc. (CPI) has been asked by growers how this information can be analyzed to provide more than just colorful maps. That is, growers want to know how this information can be analyzed in a manner that can be used for making meaningful agronomic management decisions. To begin to answer that question, CPI is on a quest to develop an agricultural technology program that takes all of the information that a grower may have from such applications and aggregates it into a system that can provide usable results for making management decisions. In the process, CPI realizes that to fully support the direction they are considering for their agricultural technology program there must also be reasonable capital expenditures in other technologies to provide a solution that answers the agronomic questions the company's customers have. While these expenditures (e.g., precision ag software, hardware, and services) may not be made initially, they will be required in later years for the program to fully benefit from the latest advances in agricultural technology.

The overall purpose of this research is to estimate models that can be used to help identify growers that are more likely to adopt specific precision agriculture technologies. Several specific objectives of this research are to:

- validate or reposition the direction that CPI management has determined is necessary to launch a program that is the most useful to growers,
- determine who the trusted sources of information are for growers, and

- identify what is important to growers in a precision agriculture program.

The research seeks to determine who the growers' main source of agronomic information is and by what means that information is received by the grower. This will provide CPI insight into how to better tailor educational programs for growers and to target their marketing efforts to make the greatest impact on crop production in South Central Nebraska. Lastly, CPI hopes to learn what other management-related decision tools growers rely on for agricultural technology and if those tools can be implemented into the program that CPI plans to launch.

Results from this research will be used to determine the interest that growers within the Cooperative Producers, Inc. (CPI) trade area (South Central Nebraska and North Central Kansas) have in gaining access to an agricultural technology program that utilizes site-specific data in making management decisions. This new technology uses previously collected data from growers and apply it to an analysis tool that returns usable results that can be applied to each field on a site-specific level. The objective of this research is to validate or reposition the direction that management has determined is necessary to launch a program that is the most useful to growers. The research seeks to determine who the growers' main source of agronomic information is and by what means that information is received by the grower. This will provide CPI insight into how to better tailor education programs for growers to make the greatest impact on crop production within the CPI trade area. Lastly, CPI hopes to learn what other tools growers rely on for agricultural technology and if those tools can be implemented into the program that CPI plans to launch.

The information from this survey also seeks to determine who is the trusted source of information for the grower and if it is not CPI what is preventing that from happening and what can be done in order for CPI representatives to become a trusted source of information for the grower. When looking at the demographic information collected from the survey, it is hypothesized that more experienced growers have a stronger relationship to entities with manpower (retailers, consultants) versus less experienced growers having a stronger tie to those entities that are more information based (internet, publications). The solution to this result would be for retailers to take a more proactive approach to become a reliable source of information to the less experienced growers by being the “go to” source through trainings and workshops targeting that group of growers. This would strengthen the relationship the retailer has with the grower by providing information and services that are of the most value to the grower.

This research will be used to help determine what is important to the grower in a precision agriculture program through the eyes of the grower and to expedite the process of bringing new products and services to the market to meet the needs of the grower as those needs quickly evolve with the launch of new technologies. Another objective of this research is to examine a grower’s willingness to adopt these programs and technologies. Recently, CPI contracted with a third party firm to conduct a customer satisfaction survey. The results of that survey indicated that CPI had a Net Promoter Score (NPS) of 10% overall and a NPS for Variable Rate Technology at -33% (proprietary company report). What these numbers mean is that the companies’ NPS is positive but could be much higher as more customers are developed into “promotes” and fewer are in the “detractor” categories. This also indicates that CPI must make drastic changes in our precision agriculture program in order to be recognized as a leader in that field and move from a negative NPS to a positive one. For comparison only, Apple has a NPS of approximately 80%. It is the goal of this research to collect and analyze data that will provide information to help CPI be positioned to address potential issues identified in this survey.

Available articles address adoption rates in both the grower and retail sectors, but they make few projections about future adoption rates. To provide the most insight into questions of interest, a survey will be distributed to the patrons of CPI within their trade area. This survey will seek to answer the questions that will meet the objectives outlined previously. The survey will be made available to all CPI patrons both through a paper copy mailed out in the monthly statement and electronically by accessing an online survey through a hyperlink provided on the company website. The completed surveys will be entered into an Excel spreadsheet for detailed analysis.

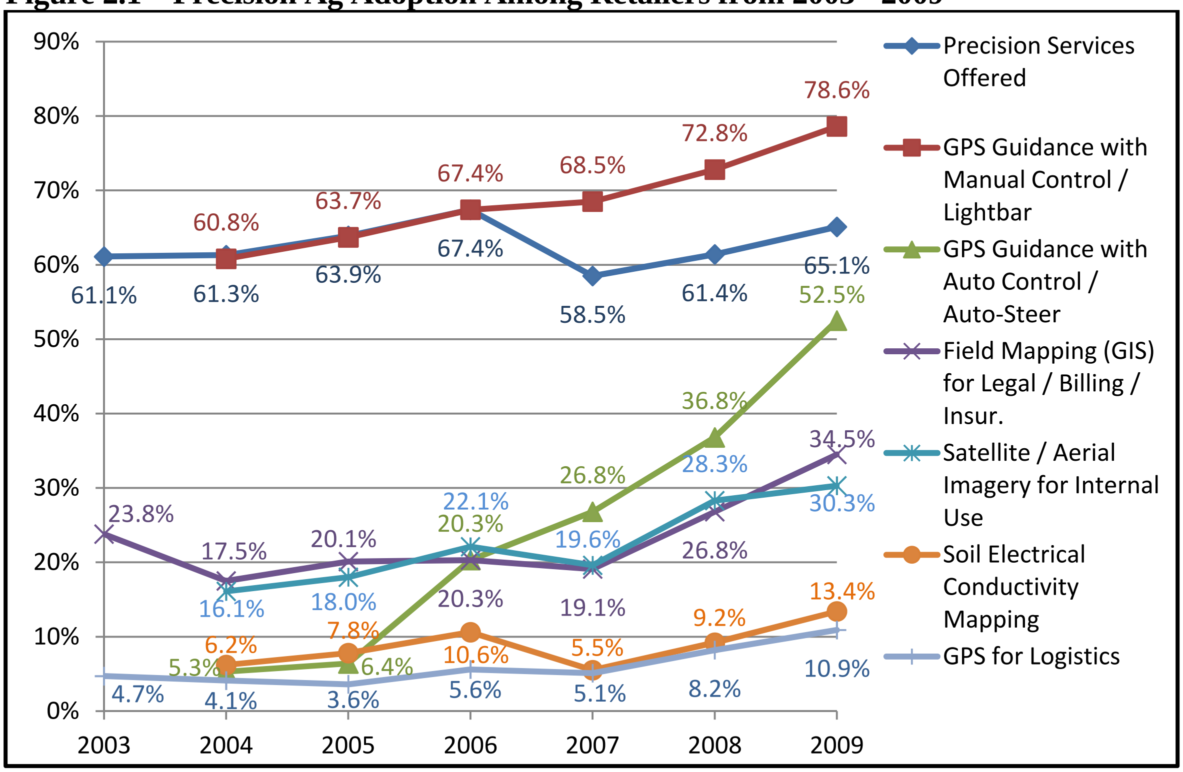
The deliverables for this project will be in the form of a written thesis presented to the Kansas State University Master of Agribusiness program. Additionally, there will be an oral presentation made to the committee for this research as well as to the program director and coordinator and others who choose to attend. The final presentation will be a combination of the written thesis and oral presentation to the board of directors and senior management team of CPI. This final presentation will provide insight and reasoning regarding the direction that the agricultural technology program will move to meet patron needs in that arena. Aside from the presentations there will be an article written that summarizes the findings and will be printed in the *CropLife* publication at the request of the editor.

CHAPTER II: LITERATURE REVIEW

Under the topic of adoption of precision agriculture by growers, much of the research is focused on the adoption of technology by those growers and governments in third-world and/or developing countries. Relative to the practice of precision agriculture, there is little information that has been analyzed pertaining to the decisions American farmers use for adoption of precision agriculture, or agricultural technology practices. Based on personal observations, it appears that when commodity prices are higher than average, growers have a propensity to spend more on those practices that fall under the heading of precision agriculture. While the information reviewed here is not a complete summary of all information related to grower adoption of precision agriculture, it does provide insight into what might lead to the adoption of precision agriculture practices by growers. Some of this information is gathered from surveys, such as *CropLife* magazine's annual agricultural retailer survey, that have been used to identify trends as a comparative indicator to the adoption practices of growers. The purpose of this review is to help identify why growers adopt precision agriculture practices and the phases that are passed through on the path to adoption.

Whipker and Akridge (2009) have conducted an annual survey of agricultural retailers within the U.S. to understand adoption practices and help identify the direction retailers are moving to implement precision agriculture practices into their operations. They developed their survey in 1995 as the result of hesitation and concerns expressed by retailers in having a desire to adopt precision agriculture technologies. The survey has been conducted annually since that time. Since the survey was first started there have been substantial advances in seed biotechnology, crop protection chemistry, and agricultural technology tools. While there has been widespread adoption of technology (Figure 2.1), the authors note that some dealerships believe they have benefited from using precision technology while there are others that feel they have not benefited from using these technologies. Figure 2.1 shows how the overall trend in adoption of precision agriculture is generally upward except for Precision Services Offered, which has been relatively constant over the 2003 through 2009 time period. Auto Control / Auto-Steer increased sharply during the survey period indicating that retailers approved of that technology much faster than other technologies. This may be due to decreased operator fatigue, increased efficiency, or simply and overall industry adoption of that capability.

Figure 2.1 – Precision Ag Adoption Among Retailers from 2003 - 2009



* Source: (Whipker and Akridge 2009)

With the recent economic issues that have plagued the nation as a whole, there seems to be little effect on the agriculture industry and the current use and future plans for agricultural technology by retailers. Retailers expect demand to continue to increase for precision agriculture services and products mostly in the area of steering assistance. There also appears to be more investment in agricultural technology by retailers as technology continues to improve. This investment also allows retailers to collect data from these products for use in their own businesses and to improve the services they provide to growers.

Adrian (2006) explored the factors that affect the adoption of precision agriculture by U.S. growers and stated that the objectives of precision agriculture are to, among others, increase profitability, mitigate environment impact of inputs, and to record operations performed on crop fields. However, slow adoption has been observed since the mid-1980s when precision agriculture tools began to appear in mainstream agriculture. Much of the research conducted on precision agriculture since it has started to gain popularity has focused on how to properly utilize these technologies as well as the areas that implement the technologies more readily than others. However, there has been little research explaining the reasoning and attitudes growers have towards adopting precision agriculture. By focusing more effort on understanding the decisions of growers, we will be able to better understand the rate of adoption and factors that affect that rate, thereby addressing a potential limitation of previous research that does not include grower attitude. Adrian found that the *confidence in using technology* and *perceptions of net benefit* were the two main factors affecting the intention to adopt and use precision agriculture in a grower's operation.

Rezaei-Moghaddam and Saeid (2010) determined that the key to achieving sustainable agriculture is found through the successful use of precision agriculture. The goals of precision agriculture are found through improving efficiencies in production, improving quality, and conservation and protection of resources. Two main components come into play; growers are driven to increase profits to remain viable and growers are becoming more environmentally aware and implementing practices that reflect such an attitude. The authors contend that growers are more open to implementing precision agriculture practices once those practices have gone through trials to verify effectiveness and reduce risk and uncertainty. However, once the practice is put to use by a grower the relevance of trialability is reduced significantly. It was concluded that growers having a high level of confidence in using precision agriculture have a higher likelihood of adopting the technologies on their operations.

Diekmann and Batte (2010) focused on the adoption and use of precision farming technology in Ohio using data collected to determine the adoption level of agricultural technology. Numerous studies are referenced in their research and they suggest there are a number of factors that determine precision agriculture adoption by growers including farming experience and education, access to information, and attitudes and perceptions. Due to the level of expertise required to use this technology, growers' information management processes are required to improve to effectively use this technology. Surprisingly, in this study it was determined that nearly a quarter of the growers surveyed had no intentions of adopting any precision agriculture technologies in the near future. However, perhaps not as surprising is that growers of larger operations were more likely to adopt precision agriculture technology than operators of smaller farms. Overall, it was determined that the average grower considers precision agriculture to be profitable as the benefits exceed the costs of implementing those practices.

Diederen, van Meijl, and Wolters (2002) explored what makes a grower adopt innovations, geared mostly in the Netherlands. Three groups of adopters were identified and are expressed as the innovators, the early adopters, and the late adopters. One important piece of information that came from this research is that those farmers who are typically risk adverse are also less likely to utilize precision agriculture in their operations. Additionally, growers who have acted in a manner in the past (such as a late adopter) tend to act the same perpetually in the adoption of precision agriculture. There also tends to be a negative impact on adoption based on the amount of market pressure a grower experiences such as low commodity prices or high input prices.

These articles provide a brief insight into the adoption practices of growers from various backgrounds but also show similar trends in how growers adopt and implement precision agriculture in their operations. Again, as precision agriculture is relatively new to the agriculture industry, there is research that provides in-depth studies into adoption practices of American growers but there are several more studies that provide an idea of why some growers in the U.S. adopt those technologies readily while others are reluctant to make the investment. There are also numerous analyses and projects that have been conducted to determine the profitability and efficiencies gained by implementing precision agriculture practices on an operation but are not put into a format that can be used to understand grower preferences and tendencies to adopt precision agriculture. For example, see Dhuyvetter et al. (Guidance & Section Control Profit Calculator), Adamchuk (Satellite-

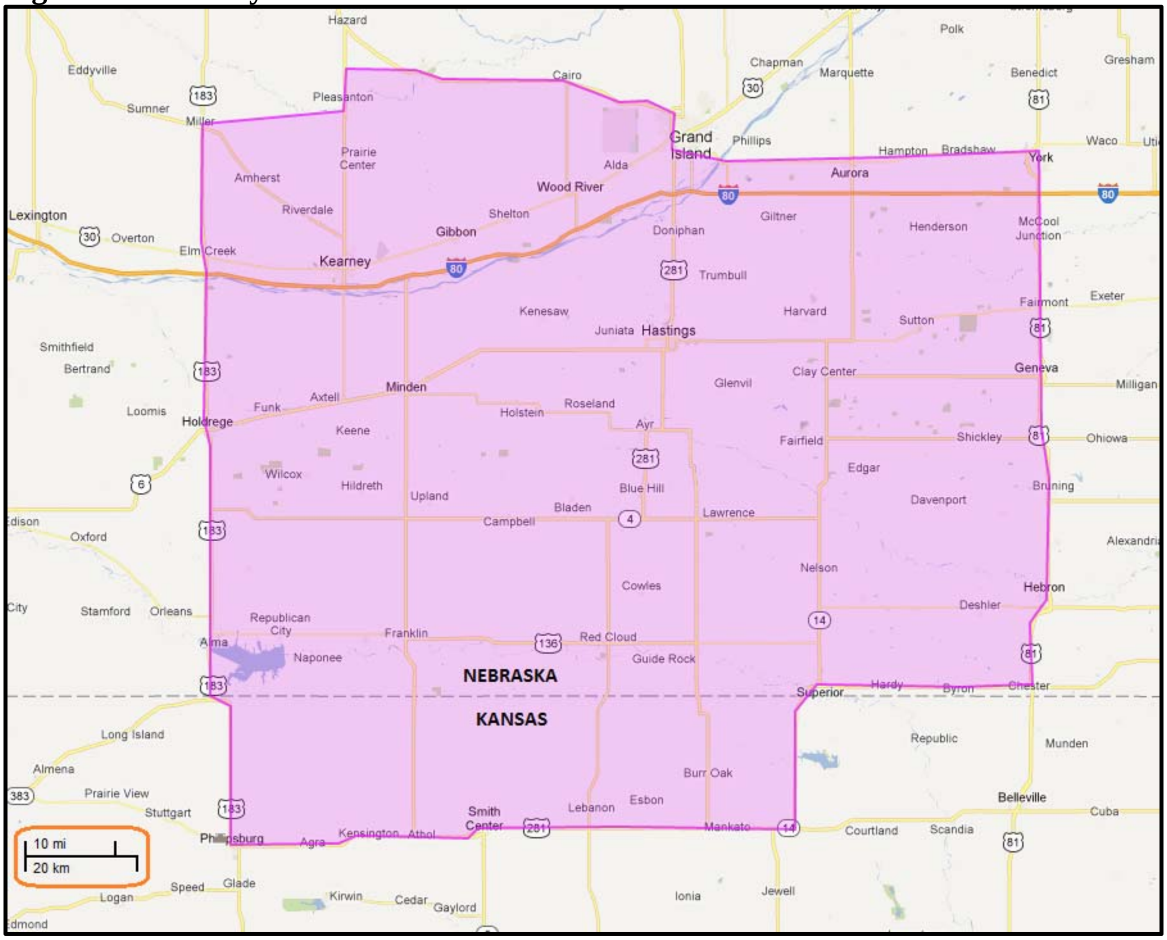
Based Auto-Guideance), Adamchuk, Doberman and Ping (Listening to the Story Told by Yield Maps), and Ferguson and Hergert (Soil Sampling for Precision Agriculture).

CHAPTER III: METHODS

3.1 Setup

The purpose of this project is to identify those growers that are likely to adopt and implement new precision agriculture programs so as to provide a more streamlined process for CPI to approach interested growers rather than inefficiently "blanketing" producers in hopes that a few will be interested. As the purpose of this project is to identify a direction for precision agriculture in South Central Nebraska and North Central Kansas (Figure 3.1), it was determined that the best approach to gather information was to go directly to those who would ultimately be affected. A survey (Appendix I) was sent to those who presumably have management responsibilities in farming operations within the CPI trade area. One question specifically asked for the respondent to identify their role in the operation as a) manager as owner, b) manager as employee, c) independent farm manager, d) absentee owner, e) employee (family), or f) employee (non-family) to confirm the responsibilities of the respondent in the operation.

Figure 3.1 – Survey Area in Nebraska & Kansas



3.2 Data Collection

The survey was sent out in CPI's regular monthly statements in hardcopy format and there was also an option for the patrons to take the survey online if they preferred that method. In total there were approximately 4,000 surveys sent out and 99 surveys wholly completed with another 15 surveys returned partially completed. This resulted in a total response (including partially completed surveys) rate of 2.88%. It is necessary to note that many of these surveys were also sent to individuals that are not actively engaged in the day-to-day operations and management of a farming operation and thus the response rate is somewhat misleading. Paper and / or online surveys were preferred over face-to-face interviews in order to maintain a high level of anonymity in an effort to encourage more responses and to save time required per survey returned.

There were four sections to the survey that respondents were asked to address with either multiple choice or ranking questions. The first section, Decision Making, asked respondents about factors that influence their decisions and to what degree their decisions are influenced by various factors. This section was designed to get a better understanding of what training and networking methods should be sought out to get the most return in customer interest. The next section, Agricultural Technology Adoption, sought to identify how much agricultural technology the grower is currently using and what plans for future use are in place on their operations. By having a solid understanding of current practices and future plans we can get a better idea of how progressive the grower in this demographic is compared to others with similar characteristics. The third section, Decision Making Process, asked the respondents how useful certain tools would be for their operations and what motivations were used when making decisions to adopt precision agriculture. This section is used to judge how important the respondents feel technologies are to the success of their operations which will help explain how new technologies will be perceived. The final section, Background and Demographics, was included to categorize the respondents to get a better understanding of how the demographic makeup affects the adoption and use of technology in farming operations. This last section will allow the respondents to be analyzed based on producer demographics to better extrapolate the results that drive the respondents to adopt and implement, or not, new technologies as they are introduced.

3.3 Modeling

The tools in econometrics that will be used for the quantitative analysis in estimating relationships among variables that are outlined in the survey will be ordinary least squares and the binomial logit model. Information from the survey will be entered into an Excel spreadsheet and the data analysis tool Stata® will be used to determine the effect individual variables have on the likelihood that a grower will adopt certain precision agricultural practices over others. With the resulting estimated models a prediction tool can be developed that will allow a user to enter variables for a given producer and be provided with an output predicting if that grower is likely or unlikely to be interested in a new precision agriculture service or product. The variables will include information about previous and current practices, impressions of precision agriculture technologies, the potential applications by the respondent, and information about the respondent's farm.

After the information is gathered and processed, it is hypothesized that the results should indicate which growers are seeking the next step in precision agriculture, which will be to analyze the information using a data driven tool. A data driven tool takes all of the information a grower has collected and compiles the layers (i.e., yield data, application maps, input prescriptions) to identify practices that have the most impact on yield. However, it is expected that the study will find, while growers are seeking to move forward with the information already collected, there will be a lack of knowledge as to what those precision agriculture programs will require to implement and understand. It is also expected that the results will also indicate that, even for the growers that currently have not adopted many of the precision agriculture practices, there is an understanding that the "farm of tomorrow" will need these tools in order to remain competitive.

CHAPTER IV: SURVEY RESULTS

The survey for this study was initially sent out in paper format on September 2, 2011 in the monthly CPI company statements. Instructions for the survey also indicated that the respondent could take the survey online by going to the homepage on the CPI website and clicking on the links available. The online survey was initially made available for a period of two months until October 31, 2011. The first offering yielded 93 responses. In the statements that were sent out on November 2, 2011 there was a reminder card included that extended the deadline for the online survey until November 30, 2011. This second offering yielded an additional 21 responses for a total of 114. The purpose of the survey was to gather information about a grower's perception and adoption of precision agriculture technologies and services. Each section will be discussed in regards to the questions asked and the answers received.

4.1 Survey Section I – Decision Making

Survey responses indicate that in the last five years 49.6% of respondents have conducted grid soil sampling on their farms, 27.9% have done zone / smart soil sampling, 50.4% have had composite soil samples taken, and 11.7% have had no formal soil sampling done on their farms (*Q1*, i.e., question number 1 in survey). Almost two-thirds (65.8%) of the respondents had conducted site-specific soil sampling, i.e., either grid or zone sampling.

Preferred methods to learn about new technologies (*Q2*) indicates that most respondents prefer to have hands on training (*Q2.1*) with 34.8% of the respondents choosing this option while the internet (*Q2.3*) was the least preferred method with only 6.3% of respondents choosing this method. Magazines, newspapers, and other printed material (*Q2.2*) and talking with others (*Q2.5*) were both chosen by 23.2% of the respondents and attending conferences (*Q2.4*) was chosen by 12.% of the respondents.

Respondents were asked to rank how much they rely on information from various outside sources with 1 having low reliance and 5 having high reliance (*Q3*). Table 4.1 reports the mean response as well as the percentage of respondents that chose a 4 or 5 for each of the sources indicating which sources they relied upon the most.

Table 4.1 – Reliance on Various Sources of Information (Q3)

Information Source (survey question)	Mean Response*	Percent 4 or 5*
Independent Crop Consultants (Q3.1)	3.45	60.71
University / Extension (Q3.6)	3.23	45.05
Farmer's Cooperative (Q3.3)	3.33	41.44
Independent Retailer (Q3.2)	3.15	38.74
Independent Research (Q3.8)	3.20	36.94
Neighboring Farmer (Q3.4)	3.05	32.43
Farm Publications (Q3.5)	3.08	32.14
USDA (Q3.7)	2.42	13.51

* Based on a 1 to 5 scale, where 1 reflects low reliance and 5 reflects high reliance.

Mean responses for the various information sources (Table 4.1) were tested for statistical differences from each other using a two-tailed paired t-test. Table 4.2 reports the p-values associated with the paired t-test of mean responses for the different information sources. Using a significance level of 90%, values of 0.10 or less indicate that the means of the two information sources are statistically different from each other, whereas, values greater than 0.10 imply the mean responses are not statistically different from each other. When analyzing the statistical differences between mean responses, the answer for USDA was found to be statistically different from all other information sources (Table 4.2). The mean values for Independent Retailer (*Q3.2*), University / Extension (*Q3.6*), and Independent Research (*Q3.8*) were not statistically different from one another at the 10% level indicating that growers value all three of these sources of information on precision agriculture similarly. The responses to this question can help CPI understand where its position is in bringing new information to growers and coordinate with those sources of information that they share a high relationship with.

Table 4.2 – t-Test Comparison for Question 3 Responses

	Q3.1	Q3.2	Q3.3	Q3.4	Q3.5	Q3.6	Q3.7	Q3.8
Mean	3.45	3.15	3.33	3.05	3.08	3.23	2.42	3.20
	p-value associated with two-tailed paired t-test of means							
Q3.1	----							
Q3.2	0.0787	----						
Q3.3	**0.6043**	**0.1747**	----					
Q3.4	0.0360	**0.4430**	0.0123	----				
Q3.5	0.0558	**0.4885**	0.0255	**0.8647**	----			
Q3.6	**0.3165**	**0.5544**	**0.4448**	**0.1845**	**0.1565**	----		
Q3.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	----	
Q3.8	**0.2082**	**0.7220**	**0.3402**	**0.2414**	**0.2299**	**0.7731**	0.0000	----

* bold and shaded values represent those pairwise comparisons that are not statistically different from each other.

The extent to which growers work with independent crop consultants is understood by asking what services are employed by growers from those consultants (*Q5*) and it was found that 69.2% obtain irrigation scheduling, 29.5% have complete crop planning, 83.3% obtain fertilizer recommendations, 85.9% get weed / insect scouting reports, and 5.1% have other services provided by crop consultants. This information indicates that while there are a high percentage of growers that use independent crop consultants, when compared to where the growers turn to for trusted sources of agronomic information, consultation services are disproportionally high. By knowing this information, CPI can be better positioned to become a trusted source of new information leading to more input on recommendations for growers' operations. This information will be more thoroughly interpreted when comparing it to the data in 4.3 Survey Section III: Decision Making Process.

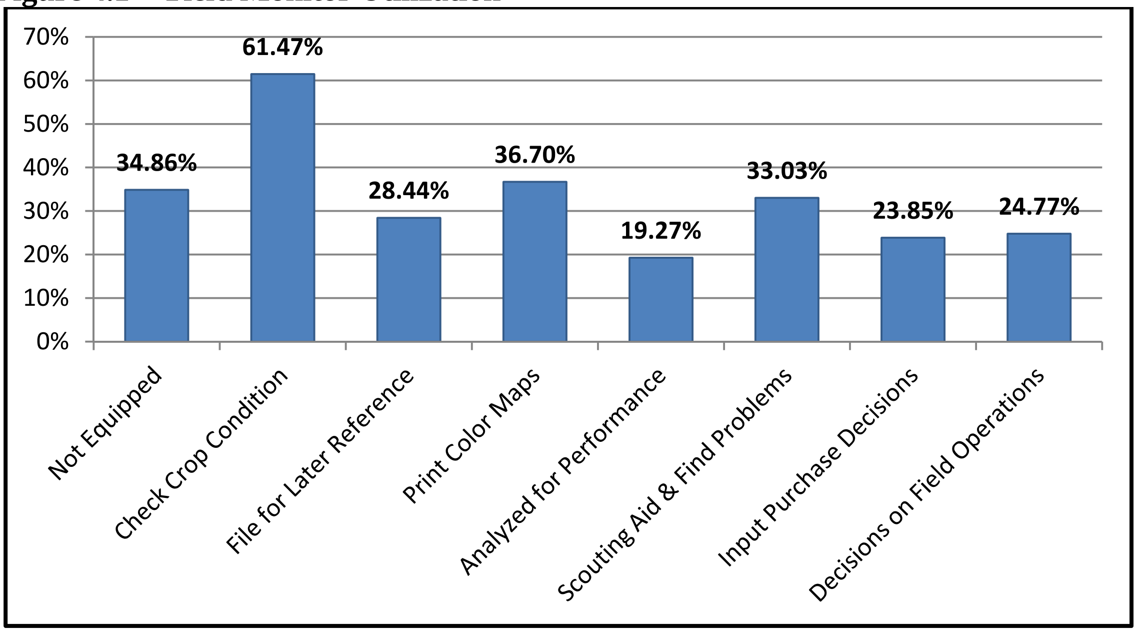
Question 6 asks growers for the approximate percentage of grain that is sold to the same company that gets their business for crop inputs. It stands out that 26.1% of customers sell no grain to the same company they buy their crop inputs from. This question helps determine if there is more loyalty to an agriculture retail company if grain is sold to and inputs are purchased from the same company.

The last questions of the first section asks about the comfort level the respondent has in sharing thoughts, ideas, and opinions with other growers depending on whether those growers are either local, regional, or national with a fourth option stating that it does not matter where they are located. Half of the growers indicated they prefer to interact with local growers while 13.4% prefer a regional setting and 36.6% state that it does not matter, none stated they prefer interacting with growers on a national level. The average response of how valuable the information is that a grower receives when interacting with other growers was 3.37 on a scale of 1 to 5 (1 = Not valuable and 5 = Highly valuable).

4.2 Survey Section II – Agricultural Technology Adoption

Respondents were asked how data recorded by their yield monitor are used (*Q9*) and the results are summarized in Figure 4.1. It was found that yield monitors are most commonly used to monitor crop condition while harvesting and the data are least likely to be analyzed using software to determine hybrid / varietal performance. As new programs are put in place, yield data will likely be critical to making solid recommendations. Knowing that yield monitors are not being utilized to maximum potential, CPI can educate growers in how that information can be used and how critical it is to collect calibrated yield data in order to make sound agronomic management decisions.

Figure 4.1 – Yield Monitor Utilization



* Percentages do not add to 100% as the respondents had the option to select more than one choice for this question.

Growers were asked about their use of or intentions to use site-specific soil sampling that includes grid or zone sampling but not composite sampling (*Q10*). Half of the respondents indicated they would continue using site-specific sampling in their operation with another 16.5% stating they have intentions to begin using this practice within the next two years. Somewhat surprising is that one-third of respondents indicated they have no intentions of using this practice in their operations.

The last two points to analyze in this section address the topic of GPS signals and variable rate irrigation acceptance. For GPS signal, 39.8% of respondents indicated they use a Real-Time Kinematic (RTK) signal, which is a sub-inch accurate signal for auto-steer purposes, with another 31.5% of respondents stating that they do not use a GPS signal in their operations. The rest of the responses were scattered among the remaining six options with the next highest being John Deere's GreenStar 1 / 2 at 14.8%. Lastly, 94.4% of respondents indicated that they have no system for variable rate irrigation. This response is not surprising as this is the newest of the precision agriculture technologies that has been introduced and it is still in the early stages of introduction and adoption.

4.3 Survey Section III – Decision Making Process

This section sought to determine what drives customers' decision making process in regards to adopting and utilizing precision agriculture programs. In developing a new precision agriculture program at CPI, the first question in this section (*Q14*) will be the most helpful in understanding the demographic and demand for components of a new program. Respondents were asked to rank how helpful various services would be for their operations on a 1 to 5 scale, where 1 = No Help and 5 = Very Helpful. From the average of the responses it is determined that soil type mapping (*Q14.4*) with an average response of 3.45, soil moisture probes (*Q14.5*) with an average of 3.45, and marketing projections and forecasting (*Q14.9*) at 3.44 are the most desirable components to a new program that can be offered. It is interesting that the first two answers have identical averages but looking at the correlation they are not highly correlated to one another. Those components that are not considered to be very helpful are a data driven tool (*Q14.3* = 3.04), bundled services (*Q14.6* = 2.85), bundled input programs (*Q14.7* = 2.76), and product receiving technology (*Q14.8* = 2.38). It is quite possible that the low ranking for the first of these three is the fact that there is little known about them and the respondents were uncertain how an undefined component would fit into their operations, therefore, prompting a lower score to be given. This information will allow CPI to develop a better understanding of those goods and services that their patrons find the most helpful and perhaps those areas that the growers need to learn more about.

Comparing mean responses for question 14 with a paired t-test indicates that nearly all of the answers are statistically different from one another (Table 4.3). One notable exception to that observation is the relationship between answers for a data driven tool to support operation decisions (*Q14.2*) and bundled agricultural technology services (*Q14.6*). With a value of "1" this indicates corresponding movements between the two responses.

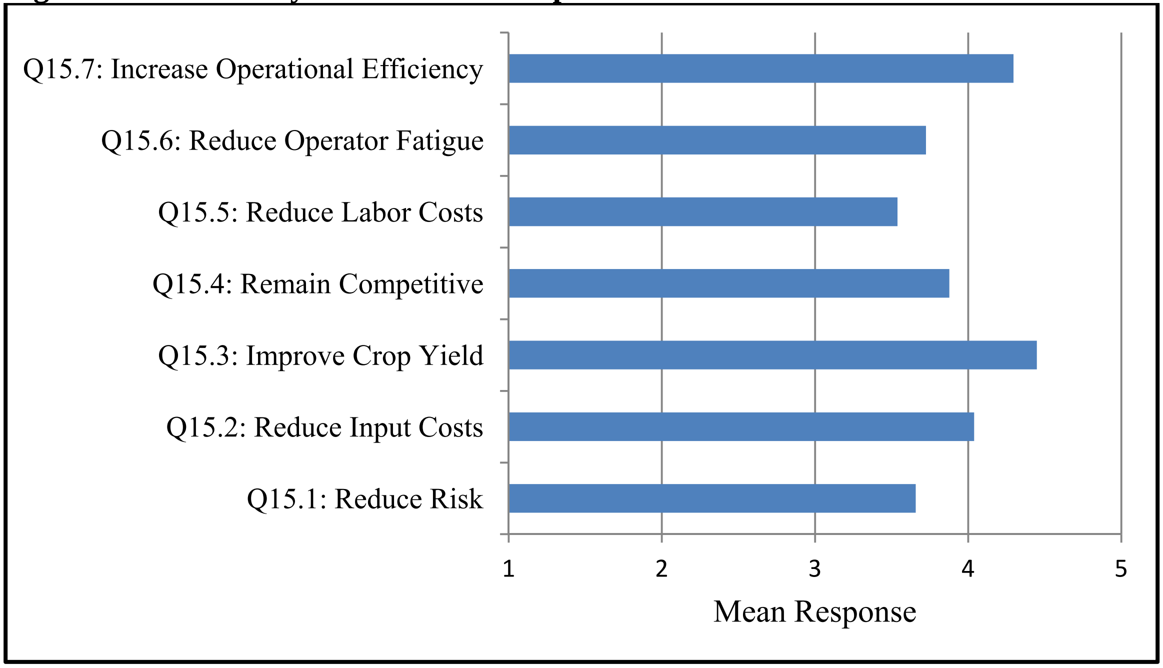
Table 4.3 – t-Stat Comparison for Question 14

	Q14.1	Q14.2	Q14.3	Q14.4	Q14.5	Q14.6	Q14.7	Q14.8	Q14.9
Mean	3.19	2.85	3.04	3.45	3.45	2.84	2.76	2.38	3.44
				p-value associated with two-tailed paired t-test of means					
Q14.1	----								
Q14.2	0.0003	----							
Q14.3	**0.1583**	0.0146	----						
Q14.4	0.0522	0.0000	0.0006	----					
Q14.5	**0.1058**	0.0001	0.0051	**1.0000**	----				
Q14.6	0.0035	**1.0000**	0.0539	0.0000	0.0000	----			
Q14.7	0.0003	**0.4272**	0.0088	0.0000	0.0000	**0.1609**	----		
Q14.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	----	
Q14.9	0.0913	0.0000	0.0048	**0.9450**	**0.9539**	0.0001	0.0000	0.0000	----

* bold and shaded values represent those pairwise comparisons that are not statistically different from each other.

The second question revolves around the motivations for adopting precision agriculture practices and is summarized in Figure 4.2. From the responses given it can be seen that the respondents place more emphasis on improving crop yield (4.45) and increasing operational efficiencies (4.30) by using agricultural technology practices and find it less motivating to adopt those practices for the purposes of reducing risk (3.66) and reducing labor costs (3.54). However, it is important to note that all responses were above an average of 3 indicating there is an overall motivation to adopt agricultural technology and apply those practices in part to all of these factors.

Figure 4.2 – Summary of Motivation Responses



The p-values associated with paired t-tests of the means (Table 4.5) show that answer Q15.1 (reduce risk) is least statistically different from the answers for Q15.5 (reduce labor cost) and Q15.6 (reduce operator fatigue). Most of the rest of the answers are statistically different from one another.

Table 4.4 – t-Stat Comparison for Question 15

	Q15.1	Q15.2	Q15.3	Q15.4	Q15.5	Q15.6	Q15.7
Mean	3.66	4.04	4.45	3.88	3.54	3.72	4.30
		p-value associated with two-tailed paired t-test of means					
Q15.1	----						
Q15.2	0.0000	----					
Q15.3	0.0000	0.0000	----				
Q15.4	0.0359	**0.1196**	0.0000	----			
Q15.5	**0.3533**	0.0000	0.0000	0.0013	----		
Q15.6	**0.5836**	0.0114	0.0000	**0.1775**	0.0663	----	
Q15.7	0.0000	0.0061	0.0662	0.0001	0.0000	0.0000	----

* bold and shaded values represent those pairwise comparisons that are not statistically different from each other.

The last question in this section asks about the Geographic Information System (GIS) that is used to analyze agricultural technology data. More than one answer could be selected and the majority of respondents answered that they primarily use John Deere APEX (41.2%) software followed by spreadsheets (32.4%) and then Ag Leader SMS (23.5%) with the remaining use spread out among Farmworks (7.4%), Mapshots (7.4%), SST Summit (1.5%), and other (2.9%).

4.4 Survey Section IV – Background & Demographics

The average gross income range for the survey population was found to be in the $250,001-500,000 range (Figure 4.3), to the categorized ranges: 1 = $0-100,000; 2 = $100,001-250,000; 3 = $250,001-500,000; 4 = $500,001-1,000,000; and 6 = $1,000,000+. The average farm size of the 114 respondents was 1,402 acres. Comparatively, the 2007 Nebraska Farm & Ranch Annual Report shows the average gross farm income for crops was $384,500 and an average farm size of 874 acres statewide (2007 Nebraska Farm & Ranch Annual Report 2007). There are a number of factors that could cause the values from the survey responses and the UNL gross incomes to be contradictory. For example, from two different years the commodity prices and weather patterns, directly affecting yield, could cause this difference.

For the question related to grower age, the average age of respondents fell within the survey range of 41-50 years of age (Figure 4.4). Additionally, 67.3% of respondents stated there is no younger person involved in the decision making for the operations, this number drops to 36.4% for the respondents in the 51+ age group.

Figure 4.3 – Percent of Responses for Each Gross Income Range

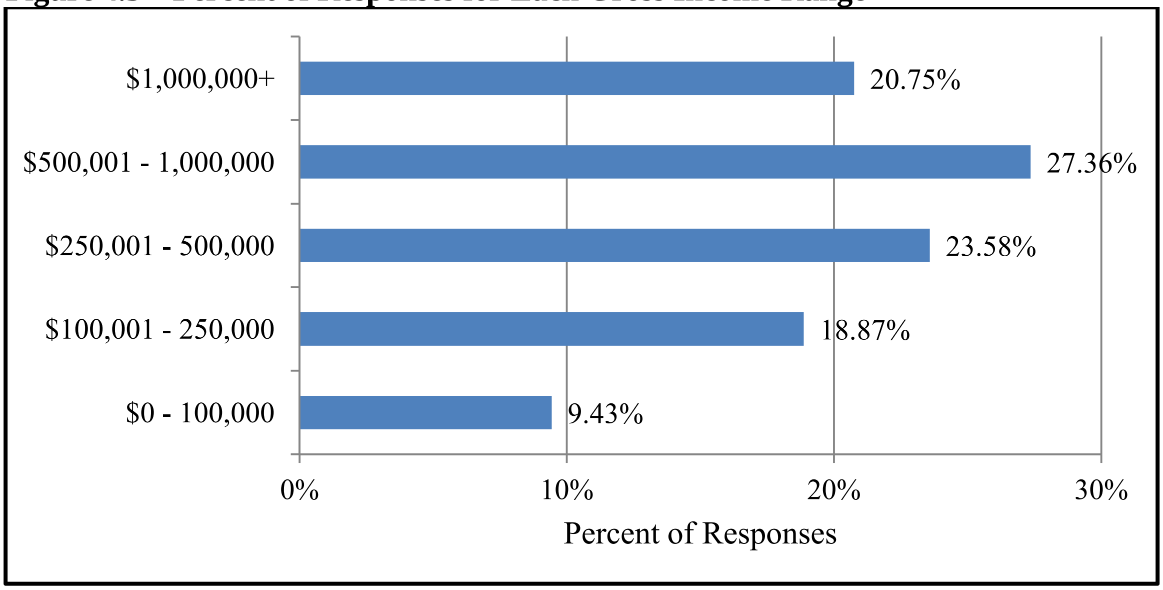
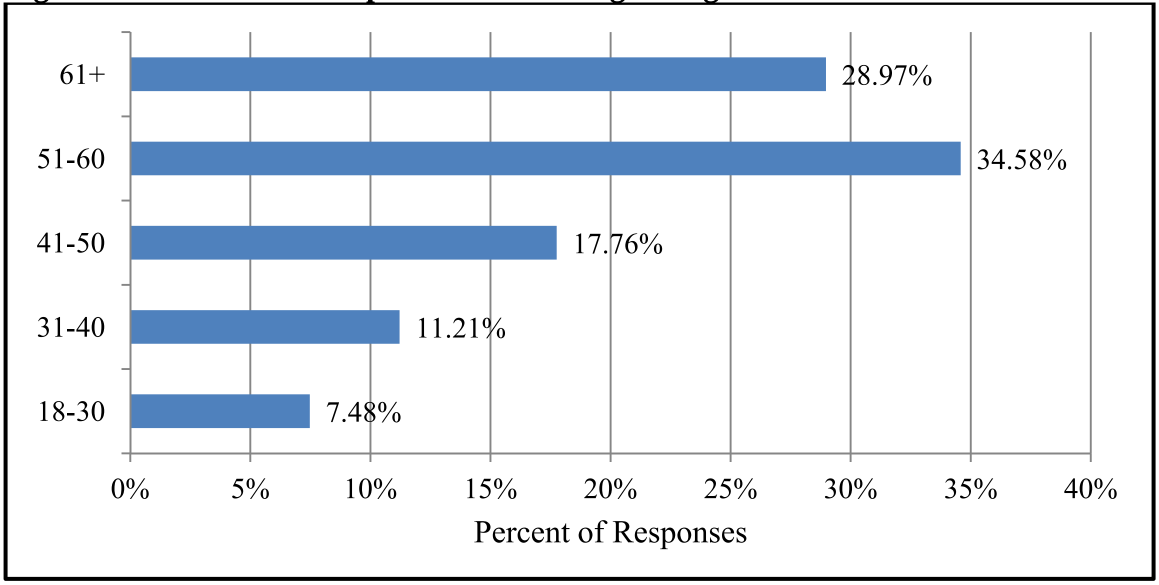


Figure 4.4 – Percent of Responses for Each Age Range



The respondents indicated that an average of 70.1% of the ground on their farms is irrigated and 45.3% of their tillable acres are rented. Knowing the percentage of acres irrigated and rented within the CPI trade area will assist in developing programs that are tailored more for the short term leases for growers seeking to push production limits with the availability of irrigation. From the growers that responded to the survey, the crops grown and their corresponding percentages are shown in Table 4.5 and compared to the averages for Nebraska. The averages shown in the table were calculated using only those respondents who indicated they grow that crop and disregarding those respondents who do not grow that crop. The columns for “Selected Crops” were chosen for comparison as there was not sufficient information from the referenced material to separate out “Seed Corn” and “Other Crops” enough to determine how they correlate to the survey responses. The averages shown are on a per farm basis for the survey responses and the statewide values. It can be seen that there are similar characteristics in percentage of crops grown for the survey area compared to the state of Nebraska. The two exceptions to that observation are that there is more wheat and alfalfa grown in the rest of the state compared to the survey area but fewer soybeans grown in the rest of the state, which seems reasonable through observation.

Table 4.5 – Crops Grown

	Survey			State of Nebraska[a]	
Crop	Acres Average	Number of Responses	Selected Crops Percent	Acres Average	Selected Crops Percent
Field Corn	797.6	100	54.23%	403.0	56.14%
Seed Corn	598.1	8	3.25%	n/a	n/a
Popcorn	407.0	2	0.55%	236.1	0.36%
Soybeans	514.3	91	31.82%	230.7	23.42%
Wheat	212.5	41	5.92%	244.4	12.00%
Grain Sorghum	159.7	7	0.76%	124.5	1.45%
Alfalfa	92.4	26	1.63%	73.3	6.63%
Other Crops	178.7	15	1.82%	n/a	n/a

[a] This data was selected from the USDA Census of Agriculture (United States Department of Agriculture 2009)

The last question of the survey asked respondents to offer input on the tillage practices implemented on their operations. A large majority of respondents use continuous no-till systems with 49.7% of the responses followed by ridge-till at 25.0%. In considering the amount of ground that still uses gravity irrigation, the ridge-till figure is not surprising but will likely diminish as growers move to more center pivot systems in the future. A small percentage of respondents who use strip-till (2.6%) and intensive tillage (5.9%) systems with reduced tillage (14.7%) rounding out the remaining respondents. As tillage practices are adopted and modified, information about tillage practices will allow CPI to quickly identify the fit for tillage systems. For example, experience shows that growers who are most interested in a practice such as cover crops will be the growers that are in reduced / no-till systems compared to those who prefer intensive tillage.

CHAPTER V: MODEL DEFINITION

This project seeks to outline characteristics of growers that fall into different stages of adoption of precision agriculture programs and services and what motivates adoption to occur. As a whole, four questions are used to identify a respondent's propensity to adopt and implement precision agriculture practices. Table 5.1 lists the questions that were used as the dependent variables and also reports summary statistics of the growers' responses.

Table 5.1 – Definition of Dependent Variables

Variable	Question	Mean	Min	Max	Std dev
Q8.1	Percent of liquid fertilizer variably applied	22.57	0	87.5	32.58
Q8.2	Percent of dry fertilizer variably applied	32.06	0	87.5	35.49
Q8.3	Percent of anhydrous variably applied	11.57	0	87.5	26.79
*Q8adj**	Average percent of all fertilizer types variably applied	22.07	0	87.5	21.67
Q10	Plans on Adopting Site-Specific Sampling	0.63	0	1	0.48
Q11	Plans to Use Auto-Steer	0.72	0	1	0.45
Q12	Uses Planter Controls	0.62	0	1	0.49

* Data for question 8 that were analyzed are an aggregate of all three question 8 options and will be discussed later.

The two types of models estimated to quantify the relationships between precision agriculture adoption and grower characteristics were the binomial logit and linear regression models. Binomial logit (BNL) models are used when the dependent variable is binary as the estimation techniques avoid unboundness problems (Studenmund 2011). A linear regression model is a regression estimation technique that calculates the empirical best guess ($\hat{\beta}$) of the true regression coefficients (β) in order to minimize the sum of the squared residuals (Studenmund 2011). The basic setup of these models is outlined in Equations 5.1 and 5.2.

(5.1) Binomial Logit Model
$$D_i = \frac{1}{1 + e^{-[\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \epsilon_i]}}$$

(5.2) Linear Regression $$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2I} + \cdots + \epsilon_i$$

Independent variables were chosen to be the same across all four models so as to create consistency in the results. These variables were chosen as they do not rely on other questions for clarification and have more concrete answers rather than answers that are based on feelings or opinions. The independent variables used in the models estimated are summarized below:

Q_{1a} = Question 1: What type of soil sampling have you done in the last 5 years?

This has been refined to include only those respondents that indicate they have used site-specific soil sampling (grid or zone) but not composite or no sampling.

Q_{7a} = Question 7: How valuable is the information you receive when networking with those growers?

Q_9 = Question 9: How do you utilize the yield monitor in your combine?

This question asked specifically how a grower uses a yield monitor, if applicable. The resultant binary variable was then created by using those answers that indicate the respondent uses a yield monitor (1) or does not use a yield monitor (0).

Q_{17b} = Question 17: What age range do you fall in?

The answers to this question were recorded as the mid-range of the various categories.

Q_{19} = Question 19: Is there a younger person that is involved with the decision making for the operation?

Q_{20} = Question 20: How many tillable acres for crop production do you have in your farm operation?

Q_{20a} = Question 20a: What percent of crop land is irrigated?

Q_{20b} = Question 20b: What percent crop land is rented?

Q_{21} = Question 21: What is your estimated gross farm income from the 2010 crop year? This question was analyzed using dummy variables for each of the income categories and displayed as shown. As these are dummy variables the gross income range that is omitted ($1,000,000+) is what the variables below are compared against:

Q_{21c} = $0-100,000

Q_{21d} = $100,001-250,000

Q_{21e} = $250,001-500,000

Q_{21f} = $500,001-1,000,000

When the ordinary least squares model is used, the output of that model will be a numeric value. The output of the binary logistic model will provide a probability of the respondent selecting the dependent variable. The output will be interpreted by stating that anything over 0.5 indicates the respondent will be more likely to choose that option whereas anything below 0.5 indicates the respondent will be less likely to choose that option.

In setting up the four models that were estimated for this research, the same nine independent variables (Table 5.2) were selected to help explain the dependent variables. The four dependent variables address the likelihood that the respondent will adopt specific precision agriculture practices and it is hypothesized that the independent variables that will have a positive impact on adoption practices, as indicated by a positive sign in the models, will be *Q1a*, *Q7a*, *Q9*, *Q19*, *Q20*, *Q20a*, and *Q21*. As site-specific soil sampling (*Q1a*), networking information (*Q7a*), and yield monitor use (*Q9*) increases, a grower will likely want to find a valuable use for the information collected and use precision agriculture to fill that need.

Table 5.2 – Definition of Independent Variables

Variable	Question	Mean	Min	Max	Std dev.
Q1a	Use of Site-Specific Soil Sampling	0.658	0	1	0.477
Q7a	Perceived Value of Networking Information	3.366	1	5	0.959
Q9	Have a Yield Monitor in Combine	0.495	0	1	0.502
Q17b	Age – Mid-Range Values	51.879	24	65	12.298
Q19	Younger Person Involved in Operation	0.307	0	1	0.463
Q20	Number of Acres Farmed	1402.132	0	7500	1342.438
Q20a	Percent Irrigated	70.055	0	100	31.676
Q20b	Percent Rented	45.257	0	100	34.777
Q21c	Gross Farm Income – $0-100,000	0.094	0	1	0.294
Q21d	Gross Farm Income – $100,000-250,000	0.189	0	1	0.393
Q21e	Gross Farm Income – $250,001-500,000	0.236	0	1	0.427
Q21f	Gross Farm Income – $500,000-1,000,000	0.274	0	1	0.448

It is hypothesized that having a younger person in the operation (*Q19*) will encourage a more experienced grower to consider precision agriculture technologies to make their operation more attractive. Additionally, as the number of acres (*Q20*) and amount of irrigation (*Q20a*) it is assumed that a grower would be more likely to adopt precision agriculture as there is more intensive management and a desire to gain efficiencies of assets. Conversely, it is hypothesized that the age mid-range variable (*Q17b*) and percent of acres rented (*Q20b*) will have a negative impact on the dependent variable and thus estimated coefficients for these variables will have a negative sign. The coefficients for gross farm income (*Q21c* to *Q21f*) are also expected to be negative as these dummy variables are all compared against the largest gross income ($1,000,000+) on the survey. As a grower ages it is assumed that he will be less likely to adopt precision agriculture, which may be intimidating or misunderstood. Lastly, it is hypothesized that growers with a higher portion of their land rented will be less likely to make improvements (additional fertilizer, improved irrigation, land improvements, etc.) to a field than what can be returned and therefore they will be less likely to adopt precision agriculture and the added expense that goes with it on rented acres.

Question 8 asks the respondent to identify the percentage of acres that liquid fertilizer, dry fertilizer, and anhydrous are variably applied to on their farm. The respondents' answers for this question were then assigned mid-range values that split the difference of the range answer (e.g., 1-25 = 12.5, 26-50 = 37.5, 51-75 = 62.5, and 76-100 = 87.5). These mid-range answers were then averaged among the three application methods and these average values were used as the dependent variable (*Q8adj*) for this analysis. As such, a linear regression model was estimated in order to identify factors impacting the percentage of acres that have fertilizer applied variably. The answers to question 8 indicate that the majority of respondents do not apply any fertilizer variably with 56.5% of respondents choosing "Do Not Apply Variably" for liquid fertilizer, 43.5% for dry fertilizer, and 77.8% for anhydrous. The average percentages for liquid, dry, and anhydrous were at 22.6%, 32.1%, and 11.6%, respectively, indicating that on average less than half of any fertilizer type is applied variably. However, if a respondent chooses "Do Not Apply Variably" that only means that fertilizer type is not applied variably and not that it is not applied, leading to a potential weakness of this model that is discussed later.

Question 10 seeks to identify if a grower intends to conduct site-specific soil sampling (grid or zone) within the next two years. Because the dependent variable is a yes (i.e., it is or will be used within the next two years = 1) or no (i.e., no plans to use site-specific sampling = 0) binary choice in this case, a BNL model was estimated. Even with less than half of the respondents indicating that they apply fertilizer variably across all choices in question 8, 49.8% of the respondents indicated they will continue to use site-specific soil sampling in their operations. The respondents indicate that 33.9% have not used and will not use site-specific soil sampling within the next two years.

Plans to use auto-steer in the operation was addressed in question 11 by asking the respondent if there are intentions to continue using this technology or begin using it within the next two years compared to those who have no plans to use auto-steer. This question also uses a BNL model as the response for this question is binary. If the respondent answered that they will continue to use this technology for planting, will continue to use this technology for field operations, or plans to begin using this technology within the next two years they received a “1” and if they answered that there are no plans to use this technology they received a “0”. Approximately three-fourths of the respondents (75.2%) indicated they will continue to use or plan to use auto-steer in the next two years. The breakdown of these producers is 59.6% are currently using this technology and 15.6% plan to begin using it within the near future.

Variable rate planting is beginning to gain popularity as this technology moves past the “early adopter” stage and is addressed in question 12. The question is analyzed using a BNL model as the response to the question was measured as a binary variable. If the respondent is using or plans to use this technology within the next two years the variable is coded as a one (1) and if he has no plans to use this technology it is coded as a zero (0). With this question the respondent could choose multiple answers but if the grower chose the first answer (“No, I have no plans to use this”) then it is likely that they would not have chosen any of the next possible answers. With this in mind, 38.9% of the respondents indicated that they have no inclination to adopt variable rate planting

CHAPTER VI: DATA ANALYSIS

The information gathered from the survey was analyzed using Stata® software. Even though there were 114 responses to the survey, individual respondents did not always answer all questions and thus models were estimated with fewer observations in some cases. The number of responses used for the analysis in Stata® ranged from 100 to 102. In discussing statistical confidence of coefficients, t-statistics will be evaluated using a two-tailed t-test at the 90% level of significance meaning that the null hypothesis that the coefficients equal 0 will be rejected when t-values are above an approximate level of 1.658 (n=120). In all of the models the coefficients are labeled based on the question the coefficient was derived from (e.g., Q_{20} = Question 20).

6.1 Question 8 Model Estimation

Beginning with the analysis on question 8, addressing the percent of acres the respondent has applied variably, the ordinary least squares regression results are reported in Table 6.1. The calculated r-squared from this model is 0.311 and the adjusted r-squared is 0.218 which indicates that this model has a relatively low ability to predict accurate outcomes. However, based on the t-statistic values the null hypothesis is rejected for any of the coefficients that have a value greater than 1.680 in absolute value. The variables that are significantly different from zero are whether or not a producer has site-specific soil sampled (*Q1a*), having a younger person involved in the operation (*Q19*), and percent of acres rented (*Q20b*). All three significant variables had the same sign as expected, i.e., positive relationship with site-specific soil sampling and having a younger person involved and a negative relationship with acres rented.

Table 6.1 – Estimation of Question 8 (Amount of Fertilizer Applied Variably)

Variable	Coefficient	Std. Error	t-stat	p-value
Q1a	14.664	4.463	3.29	0.001
Q7a	1.443	2.148	0.67	0.504
Q9	-0.686	4.857	-0.14	0.888
Q17b	-0.173	0.181	-0.96	0.340
Q19	12.066	4.309	2.80	0.006
Q20	-0.001	0.002	-0.31	0.755
Q20a	0.045	0.073	0.61	0.543
Q20b	-0.116	0.059	-1.98	0.050
Q21c	9.054	11.093	0.82	0.417
Q21d	1.922	8.774	0.22	0.827
Q21e	-8.290	8.249	-1.00	0.318
Q21f	-0.330	7.060	-0.05	0.963
Intercept	16.227	15.768	1.03	0.306
Adjusted r-squared	0.218			
RMSE	18.559			
Number of observations	102			

Table 6.2 reports the results of the estimation when the dependent variable is switched from the average midrange value for variable application of all three fertilizer sources to the midrange of variable application of dry fertilizer only (*Q8.2*). This change in model setup lowers the r-squared from 0.311 in the first estimation of the model to 0.289 in the revised model. It would seem that the first model is better, but there are some potential weaknesses with both models given the way question 8 was worded. In hindsight, the question should have included an option for “Do Not Apply This Source” to the choices of answers that would expand on the option of “Do Not Apply Variably” as this would better characterize what producers actually do and would likely result in a better fit of the model.

Table 6.2 – Estimation of Question 8 (Amount of Dry Fertilizer Applied Variably)

Variable	Coefficient	Std. Error	t-stat	p-value
Q1a	32.660	7.584	4.31	0.000
Q7a	2.925	3.650	0.80	0.425
Q9	-2.080	8.255	-0.25	0.802
Q17b	0.016	0.307	0.05	0.958
Q19	15.349	7.323	2.10	0.039
Q20	0.000	0.004	0.07	0.945
Q20a	-0.029	0.125	-0.23	0.816
Q20b	-0.055	0.100	-0.55	0.581
Q21c	17.192	18.851	0.91	0.364
Q21d	-2.828	14.912	-0.19	0.850
Q21e	-3.804	14.019	-0.27	0.787
Q21f	8.703	11.998	0.73	0.470
Intercept	-2.447	26.797	-0.09	0.927
Adjusted r-squared	0.194			
RMSE	31.54			
Number of observations	102			

In the first estimation for *Q8* (results reported in Table 6.1) the coefficient for the number of tillable acres farmed (*Q20*) is small enough that it will have little effect on the overall response as the dependent variable will be a value between 0 and 87.5 and the variable for tillable acres (*Q20*) will have a maximum value of 1.5 using the maximum value from the survey of 7,500. Of the six coefficients that have negative signs, the one that is somewhat surprising was tillable acres (*Q20*). That variable was expected to have a positive impact therefore increasing the likelihood that a grower would adopt variable rate fertilizer application as an increase in tillable acres would lead to a more focused management strategy. One of the coefficients that is positive that is unexpected is the coefficient for the gross income range of $0-100,000 (*Q21c*). This coefficient is unexpected due the value being so large (17.192) indicating that, since this is a dummy variable compared to the highest gross income range ($1,000,000+), respondents answering in this range are much more likely to apply variable rate dry fertilizer than those in the highest gross income range. The variables that are significantly different from zero are whether or not a producer has site-specific soil sampled (*Q1a*) and having a younger person involved in the operation (*Q19*). Both significant variables had the same sign as expected, i.e., positive relationship with site-specific soil sampling and having a younger person involved.

6.2 Question 10 Model Estimation

Question 10 seeks to determine how likely respondents are to do any soil sampling based on the independent variables previously outlined. As the dependent variable for this model is a yes / no response, a binary logistic model was used in the analysis, with estimated model coefficients reported in Table 6.3 followed by the marginal effects of the model reported in Table 6.4.

Table 6.3 – Estimation of Question 10 (Site-Specific Soil Sampling)

Variable	Coefficient	Std. Error	t-stat	p-value
Q1a	3.996	0.854	4.68	0.000
Q7a	0.688	0.409	1.68	0.093
Q9	1.488	0.861	1.73	0.084
Q17b	-0.020	0.032	-0.63	0.529
Q19	-0.479	0.735	-0.65	0.515
Q20	0.000	0.000	-1.14	0.253
Q20a	-0.024	0.013	-1.90	0.057
Q20b	-0.013	0.010	-1.32	0.186
Q21c	-1.404	1.935	-0.73	0.468
Q21d	1.970	1.481	1.33	0.184
Q21e	0.303	1.337	0.23	0.821
Q21f	0.999	1.122	0.89	0.373
Intercept	-1.130	2.400	-0.47	0.638
Pseudo r-squared	0.440			
Number of observations	102			

Table 6.4 – Marginal Effects of Question 10 (Site-Specific Soil Sampling)

Variable	dy/dx	Std. Error	z	p-value

Q1a	0.452	0.050	9.12	0.000
Q7a	0.078	0.045	1.74	0.081
Q9	0.168	0.094	1.80	0.072
Q17b	-0.002	0.004	-0.63	0.528
Q19	-0.054	0.083	-0.65	0.513
Q20	0.000	0.000	-1.16	0.247
Q20a	-0.003	0.001	-2.03	0.042
Q20b	-0.002	0.001	-1.35	0.176
Q21c	-0.159	0.217	-0.73	0.464
Q21d	0.223	0.163	1.37	0.171
Q21e	0.034	0.151	0.23	0.820
Q21f	0.113	0.125	0.90	0.368

When the BNL model is estimated using *Q10* as the dependent variable (plan on adopting site-specific soil sampling), the resulting pseudo r-squared is 0.440. In other studies it was found that dropping a significant covariate results in a notable decrease in the values of pseudo r-squared, while no significant change occurs if the insignificant covariates are dropped (Hu, Shao and Palta 2006). Therefore, a pseudo r-squared is read in a similar fashion as an r-squared from a linear regression.

The table for marginal effects (Table 6.4) of the model provides more insight into the variables that have a greater effect on the model. The marginal effects values are read in the same manner that coefficients from an linear regression are interpreted. To illustrate how the marginal effect values are interpreted, if a respondent uses, or has used, site-specific soil sampling (*Q1a* = 1) then they are 45.2% more likely to do site-specific sampling in the future (i.e., marginal effect of *Q1a* = 0.452). Similarly, a producer that uses a yield monitor (*Q9*) is 16.8% more likely to do site-specific soil sampling in the future compared to a producer without a yield monitor.

The variables that are significantly different from zero are whether or not a producer has site-specific soil sampled (*Q1a*), having a younger person involved in the operation (*Q19*), and percent of acres rented (*Q20b*). All three significant variables had the same sign as expected, i.e., positive relationship with site-specific soil sampling and having a younger person involved and a negative relationship with acres rented. Marginal effects that were statistically different from zero (at the 90% confidence level) are site-specific soil sampling (*Q1a*), high perceived value of networking (*Q7a*), yield monitor utilization (*Q9*), and percent of acres irrigated (*Q20a*). The signs on all of these coefficients were as expected with the exception of the percent of acres irrigated. A high perceived value of networking (*Q7a*) had a positive coefficient that is statistically different from zero indicating that networking a respondent perceives to be more valuable will allow them to engage in site-specific sampling. Anecdotal information indicates that as growers use and discuss site-specific sampling more often with other growers then those other growers will be more likely to use site-specific sampling as it is recommended through positive experiences.

It was hypothesized that having a higher percentage of acres irrigated would lead to a higher adoption rate; however, the marginal effect is negative. While the marginal effect of percent acres irrigated is negative, it is quite small as increasing the percent of irrigated acres 10 percentage points would reduce the probability of adopting site-specific soil sampling by about 3%. The signs on two other variables were unexpected, although the marginal effects were not statistically significant, and those were having a younger person involved in the operation (*Q17b*) and total acres farmed (*Q20*). The marginal effect of both of these variables was hypothesized to be positive, but both were negative in the model estimated.

6.3 Question 11 Model Estimation

As with the model for *Q10*, the model estimated for *Q11* was based on the binary logistic model as the output is measured as a yes / no response. This question seeks to determine what variables drive a grower to use automatic steering (auto-steer) systems in their operations. The results of this model are reported in Table 6.5 with the marginal effects of the model displayed in Table 6.6.

Table 6.5 – Estimation of Question 11 (Auto-Steer)

Variable	Coefficient	Std. Error	t-stat	p-value
Q1a	1.768	0.799	2.21	0.027
Q7a	0.314	0.381	0.82	0.410
Q9	1.534	0.869	1.77	0.077
Q17b	0.014	0.035	0.41	0.685
Q19	0.569	0.829	0.69	0.493
Q20	0.002	0.001	1.77	0.077
Q20a	-0.007	0.013	-0.51	0.612
Q20b	0.008	0.010	0.78	0.432
Q21c	-15.371	2087.781	-0.01	0.994
Q21d	-14.127	2087.780	-0.01	0.995
Q21e	-14.947	2087.780	-0.01	0.994
Q21f	-13.451	2087.780	-0.01	0.995
Intercept	10.865	2087.782	0.01	0.996
Pseudo r-squared	0.429			
Number of observations	102			

Table 6.6 – Marginal Effects of Question 11 (Auto-Steer)

Variable	dy/dx	Std. Error	Z	p-value
Q1a	0.182	0.073	2.51	0.012
Q7a	0.032	0.039	0.83	0.404
Q9	0.158	0.083	1.90	0.058
Q17b	0.001	0.004	0.41	0.685
Q19	0.059	0.085	0.69	0.489
Q20	0.000	0.000	1.90	0.057
Q20a	-0.001	0.001	-0.51	0.612
Q20b	0.001	0.001	0.80	0.426
Q21c	-1.582	214.910	-0.01	0.994
Q21d	-1.454	214.910	-0.01	0.995
Q21e	-1.539	214.910	-0.01	0.994
Q21f	-1.385	214.910	-0.01	0.995

The resultant pseudo r-squared value for this model was 0.429. This value is similar to the model for site-specific sampling (*Q10*). Negative coefficient values for all of the gross income responses indicates that the respondents in these income ranges are less likely to adopt and utilize auto-steer technology than those in the highest gross income level ($1,000,000+). However, the p-values for all of these responses are also high leading to the conclusion that these variables are not statistically different from zero. The variables that are significantly different from zero are whether or not a producer has site-specific soil sampled (*Q1a*), use of a yield monitor (*Q9*), and the number of tillable acres for crop production (*Q20*). All three significant variables had the same sign as expected, i.e., positive relationship.

6.4 Question 12 Model Estimation

The last question to be analyzed, *Q12*, deals with the use and planned use of automated planter control and the likelihood of adopting this technology. The results of this binomial logistic regression are shown in Table 6.7 and the marginal effects of the model are shown in Table 6.8.

Table 6.7 – Estimation of Question 12 (Automated Planter Control)

Variable	Coefficient	Std. Error	t-stat	p-value
Q1a	2.020	0.663	3.04	0.002
Q7a	-0.410	0.314	-1.30	0.192
Q9	1.153	0.668	1.72	0.085
Q17b	-0.068	0.031	-2.23	0.026
Q19	0.808	0.661	1.22	0.222
Q20	0.000	0.000	0.33	0.745
Q20a	-0.012	0.011	-1.04	0.298
Q20b	0.010	0.009	1.09	0.275
Q21c	-2.918	2.179	-1.34	0.181
Q21d	-0.895	1.662	-0.54	0.590
Q21e	-1.093	1.562	-0.70	0.484
Q21f	-1.065	1.378	-0.77	0.440
Intercept	4.695	2.803	1.67	0.094
Pseudo r-squared	0.371			
Number of observations	100			

Table 6.8 – Marginal Effects of Question 12 (Automated Planter Control)

Variable	dy/dx	Std. Error	z	p-value
Q1a	0.275	0.073	3.74	0.000
Q7a	-0.056	0.041	-1.35	0.178
Q9	0.157	0.086	1.83	0.067
Q17b	-0.009	0.004	-2.45	0.014
Q19	0.110	0.088	1.25	0.210
Q20	0.000	0.000	0.33	0.744
Q20a	-0.002	0.002	-1.06	0.290
Q20b	0.001	0.001	1.11	0.267
Q21c	-0.397	0.289	-1.37	0.171
Q21d	-0.122	0.225	-0.54	0.589
Q21e	-0.149	0.211	-0.70	0.482
Q21f	-0.145	0.186	-0.78	0.437

This model has a lower pseudo r-squared value than the previous two BNL models at 0.371, but still indicates a good fit. From Table 6.8 it is observed that again the gross income values are all negative but also have high p-values indicating they not are statistically different from zero. This is expected as the four dummy variables used represent the income ranges below $1,000,000. This indicates that respondents in the top income range are more likely to use automated planter controls than those in the other income ranges.

The variables that are significantly different from zero are whether or not a producer has site-specific soil sampled (*Q1a*), use of a yield monitor (*Q9*), and the age variable (*Q17b*). All three significant variables had the same sign as expected, i.e., positive relationship with site-specific soil sampling and yield monitor use and a negative relationship with the age variable. The sign for the age variable (*Q17b*) indicates that older producers are less likely to use automated planter control. What is surprising is that as the irrigated percentage (*Q20a*) increases the use of automated planter control decreases, even though it is at a very small rate.

6.5 Implementation

With the estimations of the linear regresion and binomial logistic (BNL) regressions completed, Table 6.9 shows the model-predicted values when the independent variables for each of the individual respondents are entered into the corresponding models. These values are simply calculated by multiplying the independent variables for each respondent by the coefficients for the models shown in Chapter 6.

Table 6.9 – Model-Predicted Values for Each Survey Respondent[a]

Respondent	LR – *Q8adj*	BNL – *Q10*[b]		BNL – *Q11*[b]		BNL – *Q12*[b]	
1	29.4	0.985	1	0.754	1	0.448	0
2	13.4	0.107	0	0.744	1	0.289	0
3	2.7	0.317	0	0.757	1	0.317	0
4	24.9	0.885	1	1.000	1	0.992	1
5	20.3	0.952	1	0.985	1	0.915	1
6	38.7	0.993	1	0.689	1	0.714	1
7	36.7	0.996	1	1.000	1	0.994	1
8	25.1	0.940	1	0.894	1	0.915	1
9	33.5	0.875	1	1.000	1	0.938	1
10	35.2	0.976	1	0.998	1	0.939	1
11	4.8	0.309	0	0.973	1	0.537	1
12	13.0	0.022	0	0.785	1	0.363	0
13	16.0	0.942	1	0.947	1	0.921	1
14	14.3	0.864	1	0.745	1	0.508	1
15	23.5	0.988	1	0.983	1	0.940	1
16	32.3	0.972	1	1.000	1	0.998	1
17	32.5	0.873	1	0.981	1	0.929	1
18	5.7	0.872	1	0.949	1	0.872	1
19	31.2	0.997	1	0.912	1	0.676	1
20	26.1	0.577	1	0.356	0	0.318	0
21	16.2	0.582	1	0.186	0	0.266	0
22	22.0	0.835	1	1.000	1	0.955	1
23	27.4	0.981	1	0.801	1	0.383	0
24	38.7	0.993	1	0.684	1	0.713	1
25	25.2	0.446	0	0.336	0	0.168	0
26	26.1	0.931	1	0.879	1	0.234	0
27	36.0	0.999	1	1.000	1	0.998	1
28	20.2	0.979	1	1.000	1	0.994	1
29	24.3	0.819	1	0.962	1	0.812	1
30	23.8	0.927	1	1.000	1	0.976	1
31	35.2	0.993	1	1.000	1	0.996	1
32	-5.1	0.062	0	0.443	0	0.171	0
33	4.7	0.757	1	0.677	1	0.321	0
34	22.0	0.835	1	1.000	1	0.955	1
35	35.2	0.993	1	1.000	1	0.996	1
36	29.9	0.080	0	0.618	1	0.060	0
37	14.7	0.240	0	0.166	0	0.154	0
38	10.2	0.452	0	0.783	1	0.853	1
39	33.4	0.658	1	0.990	1	0.768	1
40	-4.2	0.134	0	0.253	0	0.440	0
41	29.6	0.860	1	0.995	1	0.966	1
42	20.7	0.938	1	0.976	1	0.647	1
43	19.1	0.796	1	0.911	1	0.438	0
44	29.4	0.771	1	0.529	1	0.499	0

Table 6.9 Continued[a]

Respondent	LR – *Q8adj*	BNL – *Q10*[b]		BNL – *Q11*[b]		BNL – *Q12*[b]	
45	20.2	0.011	0	0.134	0	0.303	0
46	40.9	0.978	1	0.976	1	0.972	1

47	27.7	0.975	1	0.637	1	0.453	0
48	16.9	0.734	1	0.421	0	0.285	0
49	1.2	0.119	0	0.190	0	0.151	0
50	31.2	0.991	1	0.955	1	0.749	1
51	45.1	0.989	1	0.964	1	0.929	1
52	-0.4	0.070	0	0.316	0	0.081	0
53	18.2	0.529	1	1.000	1	0.893	1
54	34.1	0.795	1	1.000	1	0.970	1
55	33.0	0.902	1	0.292	0	0.134	0
56	34.2	0.994	1	0.789	1	0.902	1
57	28.5	0.949	1	0.999	1	0.863	1
58	42.0	0.873	1	0.709	1	0.719	1
59	17.6	0.536	1	1.000	1	0.968	1
60	26.3	0.963	1	0.981	1	0.721	1
61	13.9	0.355	0	0.627	1	0.419	0
62	15.0	0.947	1	0.859	1	0.626	1
63	1.4	0.072	0	0.224	0	0.181	0
64	21.2	0.940	1	1.000	1	0.949	1
65	30.0	0.659	1	1.000	1	0.980	1
66	27.2	0.927	1	0.992	1	0.832	1
67	1.5	0.051	0	0.952	1	0.454	0
68	13.4	0.432	0	1.000	1	0.971	1
69	21.5	0.828	1	0.317	0	0.370	0
70	17.7	0.975	1	0.960	1	0.954	1
71	40.0	0.982	1	0.999	1	0.881	1
72	0.0	0.386	0	0.351	0	0.130	0
73	8.2	0.111	0	1.000	1	0.718	1
74	22.1	0.019	0	0.047	0	0.007	0
75	23.6	0.931	1	1.000	1	0.976	1
76	6.6	0.240	0	0.192	0	0.073	0
77	14.0	0.261	0	1.000	1	0.935	1
78	36.6	0.932	1	1.000	1	0.949	1
79	19.6	0.858	1	1.000	1	0.996	1
80	27.8	0.978	1	0.960	1	0.701	1
81	17.8	0.574	1	0.837	1	0.836	1
82	11.5	0.683	1	0.619	1	0.613	1
83	4.3	0.548	1	0.298	0	0.276	0
84	28.0	0.620	1	1.000	1	0.994	1
85	22.4	0.935	1	0.956	1	0.691	1
86	42.1	0.927	1	0.706	1	0.460	0
87	28.3	0.932	1	0.998	1	0.950	1
88	7.1	0.155	0	0.783	1	0.175	0

Table 6.9 Continued[a]

Respondent	LR – *Q8adj*	BNL – *Q10*[b]		BNL – *Q11*[b]		BNL – *Q12*[b]	
89	24.9	0.481	0	0.424	0	0.322	0
90	-0.1	0.059	0	0.889	1	0.174	0
91	18.3	0.142	0	0.073	0	0.020	0
92	22.2	0.958	1	0.756	1	0.795	1
93	17.0	0.837	1	0.622	1	0.333	0
94	27.9	0.424	0	0.409	0	0.087	0

95	21.6	0.750	1	1.000	1	0.972	1
96	26.0	0.910	1	1.000	1	0.944	1
97	10.6	0.525	1	0.918	1	0.235	0
98	10.8	0.688	1	0.375	0	0.239	0
99	30.8	0.689	1	1.000	1	0.976	1
100	10.1	0.689	1	0.281	0	0.130	0
101	5.4	0.066	0	0.951	1	0.480	0
102	15.1	0.856	1	0.588	1	0.885	1
103	14.5	0.634	1	1.000	1	0.977	1
104	12.7	0.010	0	0.801	1	0.574	1
105	13.0	0.042	0	0.164	0	0.028	0
106	33.7	0.967	1	0.994	1	0.825	1
107	36.9	0.747	1	1.000	1	0.907	1
108	43.1	0.990	1	0.857	1	0.944	1
109	36.6	0.954	1	0.983	1	0.544	1
110	21.0	0.941	1	0.527	1	0.455	0
111	23.8	0.438	0	1.000	1	0.271	0
112	-3.3	0.002	0	1.000	1	0.570	1
113	1.0	0.523	1	0.583	1	0.155	0
114	23.7	0.279	0	0.748	1	0.911	1
Average	21.320	0.665	0.711	0.769	0.798	0.625	0.605
Min	-5.118	0.002		0.047		0.007	
Max	45.076	0.999		1.000		0.998	
Std dev	11.869	0.336		0.284		0.326	
Percent > 0.5		71.05%		79.82%		60.53%	

[a] LR - Linear Regression; BNL – Binomial Logit

[b] The left column represents the model output for each respondent. The right column was created by changing anything below 0.5 to 0 (will not use) and anything equal to or above 0.5 to 1 (will use).

The output of the linear regression model for site-specific soil sampling (*Q8adj*) will provide the predicted amount of fertilizer that the respondent will variably apply for all three sources of fertilizer. Therefore, as the value for a respondent approaches zero (0) it is estimated that the respondent will apply less fertilizer variably.

Because the other three models were BNL the output for these models will range from 0 – 1. One way of interpreting the results for these logit models is that a predicted value below 0.5 would suggest a respondent will not adopt and / or utilize the given technology whereas a predicted value above 0.5 will be interpreted as a respondent that will adopt the technology. While the values range from 0 – 1, the interpretation is simply yes / no, or binary.

To better understand the results of the models, the data for respondent 51 indicates that this respondent will apply a higher percentage of fertilizer variably than the other respondents with an linear regression output of 45.1. That same respondent will also likely use site-specific sampling, auto-steer, and automated planter control with values of 0.989, 0.964, and 0.929, respectively. To see examples of the high and low results of the model, predicted values for respondents 27 and 74 can be observed. The data indicate that respondent 27 has values of 0.999, 1.000, and 0.998 for all three of the reported technologies indicating that this respondent will use site-specific sampling, auto-steer, and automated planter control, respectively. However, respondent 74 has very low predicted values for the dependent variables with results of 0.019, 0.047, and 0.007 for site-specific sampling, auto-steer, and automated planter control, respectively. These data show that respondent 27 is more likely to adopt and utilize precision agriculture practices whereas respondent 74 is less likely to adopt and utilize these technologies.

CHAPTER VII: CONCLUSION

The data collected from the surveys that were sent out to respondents within the CPI trade area are useful for identifying what drives the adoption of precision agriculture applications. The technologies that were chosen to be analyzed as dependent variables (percent of fertilizer variably applied, site-specific soil sampling, automated planter control, and auto-steer) can be adopted across a wide geography and grower demographic. As such, the results of this survey should be easily adapted to other geographies within the farming community. Certain characteristics may change the outcome of the models such as the absence or presence of irrigation, the types of crops grown that were not included in this survey (cotton, rice, etc.), and the economic condition of the area being surveyed. However, growers willing to adopt precision agriculture will likely adopt those practices regardless of the aforementioned deterrents. The result of this study is to more confidently identify and target those growers that are more accepting of new technologies and work with them to implement these practices as they will be more likely to fully support those efforts and give objective feedback.

The Ordinary Least Squares model that had the best fit based on the r-squared value for the amount of fertilizer applied variably (*Q8*) was found to be the model that had all three variables included ($R^2 = 0.218$) rather than just the variable for variable rate dry ($R^2 = 0.194$). Based on the former model it was found that the coefficients for site-specific sampling (*Q1a*) and a younger person involved in the operation (*Q19*) were much higher than the others and were also statistically different from zero. The coefficient for yield monitor use (*Q9*) and the age mid-range variable (*Q17b*) were negative indicating that as yield monitor use and age increase the use of variable rate fertilizer application decreases. While the variable for percent of irrigated ground (*Q20a*) is positive, the variable for percent rented ground (*Q20b*) is negative, which indicates that respondents who have more irrigated ground are more likely to apply variable rate fertilizer but as the number of rented acres increases variable rate fertilizer actually decreases. Lastly, the variable for gross income ranges $0 – 100,000 (*Q21c*) and $100,001 – 250,000 (*Q21d*) are positive. Since these dummy variables are compared against the responses for the highest gross income range (>$1,000,000) the positive coefficients indicate that the respondents in the lowest income ranges are more likely to use variable rate fertilizer than the respondents in the highest income range. However, p-values for all of the gross income variables are greater than 0.10 indicating they are not statistically different from zero.

Through the research it was found in the Binomial Logistic Models for site-specific sampling (*Q10*), auto-steer (*Q11*), and automated planter control (*Q12*) that respondents that have conducted site-specific sampling, have a higher gross income, and those that use a yield monitor will have a higher output in the model than those who do not implement those practices and are therefore more likely to adopt the practices. However, those who find more value in the information they get from networking (*Q7a*) and the respondents in a higher age range (*Q17b*) are shown to have lower predicted values from the models. This indicates they are less likely to use site-specific soil sampling, auto-steer, and automated planter control than those who find less value in information from networking and younger respondents. Across all models it was found that p-values for site-specific sampling (*Q1a*) and yield monitor use (*Q9*) are less than 0.10 indicating that the coefficients for these variables are statistically different from zero.

When considering the response rate it is likely that those customers who have a positive experience with CPI are those who chose to respond to the survey. This bias would lead to the omission of the results of those who do not do business with CPI in the outlined trade area or those who do not have a favorable opinion of CPI. The dependent variable used in the model that was estimated first for percentage of variable rate fertilizer applied (*Q8adj*) creates a weakness in the model in that there was no option for the respondent to choose that they do not apply each individual source of fertilizer. This question assumes that if the respondent does not apply each source variably then that source is at least applied as a flat rate application. To strengthen this model it would be best to include the option for the respondent to choose that a particular method of fertilizer is not applied in addition to each option for variable application.

In addition to the models estimated, this project was undertaken in order to understand grower motivations for adopting data driven tools. It was found through analyzing the mean values of responses for tools used for making data driven decisions (*Q14*) that the respondents found little value in such tools. In addition, respondents indicated there was less of a preference for bundled services. This is likely due in large part to a misunderstanding of what those terms mean rather than a perceived value in those services.

To further expand on this research more face-to-face surveys should be conducted with growers in order to be more confident in the source the information is gathered from. Rather than blanketing a general group of patrons, face-to-face surveys will allow the survey gatherers to target a particular demographic or a group of growers for which size, type of operations, and production practices are somewhat known going into the session. As precision agriculture has become widespread with growers it seems it would be beneficial for the United States Department of Agriculture to expand the Census of

Agriculture to include questions related to precision agriculture adoption and use. Since the Census of Agriculture covers growers across the nation the database would be more reliable and universal than the survey data that were collected for the research in this report. However, the data collected in this report were meant only to analyze the precision agriculture practices of growers within a defined geography.

REFERENCES

2007 Nebraska Farm & Ranch Annual Report. Annual Report, Lincoln, NE: University of Nebraska Cooperative Extension, 2007, 23.

Adamchuk, Viacheslav I. "Satellite-Based Auto-Guideance." no. EC706. Lincoln, NE: University of Nebraska Lincoln Extension, 2008.

Adamchuk, Viacheslav I., Achim Dobermann, and Jianli Ping. "Listening to the Story Told by Yield Maps." no. EC 04-704. Lincoln, NE: University of Nebraska Lincoln Extension, n.d.

Adrian, Anne M. "Factors Influencing Adoption and Use of Precision Agriculture." Auburn, AL: Auburn University, 2006.

Dhuyvetter, Kevin C., Craig M. Smith, Terry L. Kastens, and Dietrich L. Kastens. "Guidance & Section Control Profit Calculator." Manhattan, KS, 09 16, 2010.

Diederen, Paul, Hans van Meijl, and Arjan Wolters. "Moderisation in Agriculture: What Makes a Farmer Adopt an Innovation?" *Xth EAAE Congress.* Zaragoza, Spain, 2002.

Diekmann, Florian, and Marvin T. Batte. *2010 Ohio Farming Practices Survey: Adoption and Use of Precision Farming Technology in Ohio.* Survey Results, Columbus, OH: Ohio State University, 2010.

Ferguson, Richard B., and Gary W. Hergert. "Soil Sampling for Precision Agriculture." no. EC 00-154. Lincoln, NE: University of Nebraska Lincoln Extension, n.d.

Hu, Bo, Jun Shao, and Mari Palta. "Pseudo-R2 in Logistic Regression Model." *Statistica Sinica.* Vol. 16. Wisconsin: University of Wisconsin-Madison, 2006. 847-860.

Rezaei-Moghaddam, Kurosh, and Salehi Saeid. "Agricultural Specialists' Intention Toward Precision Agriculture Technologies: Integrating Innovation Characteristics to Technology Acceptance Model." *African Journal of Agricultural Research* 5, no. 11 (2010): 1191-1199.

Studenmund, A.H. *Using Econometrics: A Practical Guide - Sixth Edition.* Boston: Pearson Education, Inc., 2011.

United States Department of Agriculture. "2007 Census of Agriculture." Vol. 1. no. Geographic Area Series. Washington D.C., February 2009.

Whipker, Linda D., and Jay T. Akridge. *2009 Precision Agricultural Services: Dealership Survey Results.* Survey Results, West Lafayette, IN: Purdue University, 2009.

APPENDIX A – PATRON SURVEY

My name is Tyrell Fickenscher and I am the Ag Technology Coordinator and Wilcox location manager for Cooperative Producers, Inc. (CPI). I am in the process of completing my Masters in Agribusiness from Kansas State University and one requirement to complete that program is to write a thesis. For my research project I plan to analyze the decision making process that growers follow when making decisions on agricultural technology applications to their operations. This survey is a critical component of that analysis as I will use the results from this survey to build on previous research on this subject matter.

If possible, I would like the person most familiar with the farm operation to fill out this survey in full. All surveys are anonymous and the information contained within the survey will be used strictly for analysis within the CPI trade area and will not be distributed to other parties. This survey should only take 5–10 minutes to complete.

If you prefer to take the survey online you can go to the homepage of the CPI website at www.cpicoop.com and click the link at the top of the page labeled "Agricultural Technology Survey." If you chose to fill out the paper survey you can simply drop it off at your nearest CPI location and they will forward it to me. If you have any questions or would like a copy of the results please feel free to contact me with the information at the top of the page. Thank you for taking the time to fill this out! https://surveys.ksu.edu/TS?offeringId=182046

NOTE: For the purpose of this survey, agricultural technology is defined as technologies that help you micromanage your crops with applications such as yield & application monitors, variable rate application, & software as well as those components that make equipment operation more efficient such as guidance systems, logistics, and rate controllers.

SECTION I – DECISION MAKING

1. What type of soil sampling have you done within the last 5 years? [*circle all that apply*]

Grid Zone / Smart Sampling Composite None

2. What is your preferred method to learn about new technologies? [*check preferred method*]

___ Hands-on training in the field
___ Magazines, newspapers, and other printed materials
___ Internet
___ Attending Conferences
___ Talking with others

3. How much do you rely upon information from the following sources?

1 = No Reliance ; 5 = High Reliance

Independent Crop Consultant	1	2	3	4	5
Independent Retailer	1	2	3	4	5
Farmer's Cooperative	1	2	3	4	5
Neighboring Farmer	1	2	3	4	5
Farm Publications	1	2	3	4	5
University / Extension	1	2	3	4	5
USDA	1	2	3	4	5
Independent Research	1	2	3	4	5

4. Do you try to measure the value of agronomic information you receive from difference sources? [*check all that apply*]

___ Yes, I try to objectively estimate the reduction in input use as a result of using the information
___ Yes, I try to objectively estimate the increase in output as a result of using the information
___ No, I do not try to objectively estimate the effect of using the information

5. If you work with an independent crop consultant, what information do you obtain? [*circle all that apply*]

Irrigation Scheduling   Complete Crop Planning   Fertilizer Recommendations
Pest (Weed/Insect) Reporting   Other _______________   Not Applicable

6. To what percentage of your grain sales go to the company you purchase inputs from? [*circle* one]

None   10%   25%   50%   75%   90%   100%

7. When networking with other growers are you more comfortable sharing thoughts, ideas, and opinions if the other growers are: [*circle one*]

Local   Regional   National   Doesn't Matter

7a. How valuable is the information you receive when networking with those growers? [*circle one*]

1 = Not Valuable ; 5 = Highly Valuable   1   2   3   4   5

SECTION II – AGRICULTURAL TECHNOLOGY ADOPTION

8. What percentage of your acres do you apply the following fertilizer types using a variable rate? [*circle one for each row*]

a. LIQUID FERTILIZER	Do Not Apply Variably	1–25%	26–50%	51–75%	76–100%
b. DRY FERTILIZER	Do Not Apply Variably	1–25%	26–50%	51–75%	76–100%
c. ANHYDROUS	Do Not Apply Variably	1–25%	26–50%	51–75%	76–100%

9. How do you utilize the yield monitor in your combine? [*select all that apply*]

___ My combine is not equipped with a yield monitor
___ It is used check crop conditions (moisture, test weight, etc.) while running through the field
___ I file the information away for reference later
___ I use it to get color yield maps printed at the end of the season
___ The yield maps are analyzed in software to determine hybrid / varietal performance
___ I have used the previous year's maps as a scouting aid to find and analyze problems
___ The maps from the yield monitor are used to make input purchase decisions
___ The maps from the yield monitor are used to make decisions on field operations

10. Do you plan on using site specific soil sampling (grid or zone…not composites)? [*select one*]

___ No, I have no plans to use this practice
___ Yes, I will continue using this practice in my operation
___ Yes, I will begin using this within the next two years

11. Do you plan on using auto-steer in your operation? [*select one*]

___ No, I have no plans to use this
___ Yes, I will continue using this technology, but only for planting operations
___ Yes, I will continue using this technology for all field operations or where it works to do so
___ Yes, I will begin using this within the next two years

11a. What type of GPS signal is your auto-steer system based on? [*circle one*]

RTK   CORS   WAAS   OmniStar XP/HP   GreenStar 1 / 2   GLONASS

Other __________   Do Not Use   Do Not Know

12. Do you plan on using automated planter control on your planter? [*select all that apply*]

___ No, I have no plans to use this
___ Yes, I will <u>continue</u> using this technology to monitor the planting rate as I travel through the field
___ Yes, I will <u>continue</u> using this to change populations when going from irrigated to non-irrigated ground
___ Yes, I will <u>continue</u> using this to vary the population of the seed across a single field
___ Yes, I will <u>expand</u> on how I am using this technology
___ Yes, I will have this <u>added</u> to my planter within the next two years and start using it

13. Do you currently use a system for variable rate irrigation? [*select one*]

___ No
___ Yes

13a. Which of the following best describes your opinion of variable rate irrigation? [*select all that apply*]

___ I don't know anything about this
___ It will not develop into a useable system during my farming career
___ It is a technology in its infancy that has yet to mature
___ It has a fit but is not for me yet
___ It is the next step to take to better input management
___ It is currently helping my operation better manage water usage

<u>SECTION III –DECISION MAKING PROCESS</u>

14. How helpful would the following services be to your operation?

1 = No Help ; 5 = Very Helpful

NOTE: Bundling refers to programs that include multiple services to create a complete program.

Compiling and analyzing your historical production data	1	2	3	4	5
A data driven tool to support operation decisions	1	2	3	4	5
A data driven tool to make seed recommendations	1	2	3	4	5
Soil type mapping (CEC, EM, & EC…not NRCS soil maps)	1	2	3	4	5
Soil moisture probes for irrigation scheduling	1	2	3	4	5
Bundled agricultural technology services	1	2	3	4	5
Bundled complete crop input programs	1	2	3	4	5
Product receiving technology (RFID, Data Transfer, Barcodes)	1	2	3	4	5
Marketing projections & forecasting	1	2	3	4	5

15. Please rate your motivations for adopting agricultural technology practices on your operation.

1 = Not Considered ; 5 = Greatly Considered

Reduce Risk ____________	1	2	3	4	5
Reduce Input Costs ____________	1	2	3	4	5
Improve Crop Yield ____________	1	2	3	4	5
Remain Competitive ____________	1	2	3	4	5
Reduce Labor Costs ____________	1	2	3	4	5
Reduce Operator Fatigue ____________	1	2	3	4	5
Increase Operational Efficiency ____________	1	2	3	4	5

16. What GIS package do you use to analyze your operation's agricultural technology data? [*circle all that apply*]

Ag Leader SMS   Farmworks   Mapshots   APEX
SST Summit   Spreadsheets   Other ___________

<u>SECTION IV – BACKGROUND & DEMOGRAPHICS</u>

17. What age range do you fall in? [*circle one*]   18-30   31-40   41-50   51-60   61+

18. What is your role in the operation you have referenced in this survey? [*circle most appropriate*]

Manager as Owner   Manager as Employee   Independent Farm Manager
Absentee Owner   Employee (family)   Employee (non-family)

19. Is there a younger person that is involved with the decision making for the operation? [*circle one*]

Yes, family member   Yes, non-family employee   Yes, both family and non-family   No

20. How many <u>tillable</u> acres for crop production do you have in your farm operation? [*fill in*]   _______ ac

20a. What percent is irrigated: ____%

20b. What percent is rented: ____%

21. What is your estimated gross farm income from the 2010 crop year? [*circle one*]

$0 – 100,000 $100,001 – 250,000 $250,001 – 500,000 $500,001 – 1,000,000   1,000,000+

22. How many acres of the following cash crops did you produce on your operation in 2011? [*fill in*]

NOTE: Total should add up to acres listed on question 20.

Field Corn ____ac   Seed Corn ____ac   Soybeans ____ac   Other ___________ ____ac
Wheat ____ac   Popcorn ____ac   Sorghum ____ac   Other ___________ ____ac
Alfalfa ____ac   Sunflowers ____ac   Millet ____ ac   Other ___________ ____ac

23. What tillage practice(s) did you use on your operation in 2011? [*percentages should add to 100%*]

Intensive Tillage	Ridge Till	Strip-Till	Reduced Tillage	Continuous No-Till	
%	%	%	%	%	**= 100%**

Thank you for taking the time to complete this survey!

APPENDIX B – SURVEY SUMMARY STATISTICS

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q1:	Grid	55	1.000	1	1	0.000	BINARY
Q1:	Zone / Smart Sampling	31	1.000	1	1	0.000	BINARY
Q1:	Composite	56	1.000	1	1	0.000	BINARY
Q1:	None	13	1.000	1	1	0.000	BINARY
Q1:	Summary - Site-Specific Soil Sampling	111	0.883	0	1	0.323	BINARY
Q2:	What is your preferred method to learn about new technologies? [check preferred method]	112	2.661	1	5	1.608	MULT. CHOICE
Q3.1:	Independent Crop Consultants	112	3.446	1	5	1.599	SCALE
Q3.2:	Independent Retailer	111	3.153	1	5	1.063	SCALE
Q3.3:	Farmer's Cooperative	111	3.333	1	5	1.082	SCALE
Q3.4:	Neighboring Farmer	111	3.045	1	5	0.976	SCALE
Q3.5:	Farm Publications	112	3.080	1	5	0.978	SCALE
Q3.6:	University / Extension	111	3.234	1	5	1.235	SCALE
Q3.7:	USDA	111	2.423	1	5	1.116	SCALE
Q3.8:	Independent Research	111	3.198	1	5	1.102	SCALE

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q4:	Yes, I try to objectively estimate the reduction in input use as a result of using the information	77	1.000	1	1	0.000	BINARY
Q4:	Yes, I try to objectively estimate the increase in output as a result of using the information	80	1.000	1	1	0.000	BINARY
Q4:	No, I do not try to objectively estimate the effect of using the information	12	1.000	1	1	0.000	BINARY
Q4:	Summary - Objective Estimations Using Information	112	0.893	0	1	0.311	BINARY
Q5:	Irrigation Scheduling	54	1.000	1	1	0.000	BINARY
Q5:	Complete Crop Planning	23	1.000	1	1	0.000	BINARY
Q5:	Fertilizer Recommendations	65	1.000	1	1	0.000	BINARY
Q5:	Pest (Weed / Insect) Reporting	67	1.000	1	1	0.000	BINARY
Q5:	Other	4	1.000	1	1	0.000	BINARY
Q5:	Not Applicable	33	1.000	1	1	0.000	BINARY
Q5:	Summary - Independent Consultants Used	78	1.000	1	1	0.000	BINARY
Q6:	To what percentage of your grain sales go to the company you purchase inputs from?	111	3.171	1	7	1.887	MULT. CHOICE

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q7:	When networking with other growers are you more comfortable sharing thoughts, ideas, and opinions if the other growers are:	112	2.232	1	4	1.388	MULT. CHOICE
Q7.a:	How valuable is the information you receive when networking with those growers?	112	3.366	1	5	0.959	SCALE
Q8.1:	LIQUID FERTILIZER	108	2.120	1	5	1.508	MULT. CHOICE
Q8.2:	DRY FERTILIZER	108	2.565	1	5	1.625	MULT. CHOICE
Q8.3:	ANHYDROUS	108	1.574	1	5	1.247	MULT. CHOICE
Q9:	My combine is not equipped with a yield monitor	38	1.000	1	1	0.000	BINARY
Q9:	It is used to check crop conditions (moisture, test weight, etc.) while running through the field	67	1.000	1	1	0.000	BINARY
Q9:	I file the informtion away for reference later	31	1.000	1	1	0.000	BINARY
Q9:	I use it to get color yield maps printed at the end of the season	40	1.000	1	1	0.000	BINARY
Q9:	The yield maps are analyzed in software to determine hybrid / variety performance	21	1.000	1	1	0.000	BINARY
Q9:	I have used the previous year's maps as a scouting aid to find and analyze problems	36	1.000	1	1	0.000	BINARY
Q9:	The maps from the yield monitor are used to make input purchase decisions	26	1.000	1	1	0.000	BINARY
Q9:	The maps from the yield monitor are used to make decisions on field operations	27	1.000	1	1	0.000	BINARY

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q9:	Summary - Use Yield Maps	109	1.000	1	1	0.000	BINARY
Q10:	Do you plan on using site specific soil sampling (grid or zone...not composites)?	109	1.826	1	3	0.692	SELECT ONE
Q11:	Do you plan on using auto-steer in your operation?	109	2.596	1	4	1.028	SELECT ONE
Q11.a:	What type of GPS signal is your auto-steer system based on?	108	4.157	1	8	2.789	SELECT ONE
Q12:	No, I have no plans to use this	42	1.000	1	1	0.000	BINARY
Q12:	Yes, I will continue using this technology to monitor the planting rate as I travel through the field	32	1.000	1	1	0.000	BINARY
Q12:	Yes, I will continue using this to change populations when going from irrigated to non-irrigated ground	33	1.000	1	1	0.000	BINARY
Q12:	Yes, I will continue using this to vary the population of the seed across a single field	15	1.000	1	1	0.000	BINARY
Q12:	Yes, I will expand on how I am using this technology	17	1.000	1	1	0.000	BINARY
Q12:	Yes, I will have this added to my planter within the next two years and start using it	16	1.000	1	1	0.000	BINARY
Q12:	Summary - Use Automated Planter Control	108	0.620	0	1	0.488	BINARY
Q13:	Do you currently use a system for variable rate irrigation?	108	1.056	1	2	0.230	1=NO ; 2=YES
Q13.a:	I don't know anything about this	38	1.000	1	1	0.000	BINARY

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q13.a:	It will not develop into a usable system during my farming career	11	1.000	1	1	0.000	BINARY
Q13.a:	It is a technology in its infancy that has yet to mature	30	1.000	1	1	0.000	BINARY
Q13.a:	It has a fit but is not for me yet	28	1.000	1	1	0.000	BINARY
Q13.a:	It is the next step to take to better input management	14	1.000	1	1	0.000	BINARY
Q13.a:	It is currently helping my operation better manager water usage	4	1.000	1	1	0.000	BINARY
Q13.a:	Summary - Favorable View of Variable Rate Irrigation	108	1.000	1	1	0.000	BINARY
Q14.1:	Compiling and analyzing your historical production data	103	3.194	1	5	1.268	SCALE
Q14.2:	A data driven tool to support operation decisions	104	2.846	1	5	1.147	SCALE
Q14.3:	A data driven tool to make seed recommendations	103	3.039	1	5	1.093	SCALE
Q14.4:	Soil type mapping (CEC, EM, & EC...not NRCS soil maps)	103	3.447	1	5	1.194	SCALE
Q14.5:	Soil moisture probes for irrigation scheduling	103	3.447	1	5	1.412	SCALE
Q14.6:	Bundled agricultural technology services	103	2.845	1	5	1.178	SCALE
Q14.7:	Bundled complete crop input programs	103	2.757	1	5	1.232	SCALE
Q14.8:	Product receiving technology (RFID, Data Transfer, Barcodes)	103	2.379	1	5	1.086	SCALE

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q14.9:	Marketing projections & forecasting	103	3.437	1	5	1.177	SCALE
Q15.1:	Reduce Risk	105	3.657	1	5	1.142	SCALE
Q15.2:	Reduce Input Costs	105	4.038	1	5	1.018	SCALE
Q15.3:	Improve Crop Yield	105	4.448	1	5	0.808	SCALE
Q15.4:	Remain Competitive	105	3.876	1	5	1.166	SCALE
Q15.5:	Reduce Labor Costs	104	3.538	1	5	1.238	SCALE
Q15.6:	Reduce Operator Fatigue	105	3.724	1	5	1.244	SCALE
Q15.7:	Increase Operational Efficiency	105	4.295	1	5	0.831	SCALE
Q16:	Ag Leader SMS	16	1.000	1	1	0.000	BINARY
Q16:	Farmworks	5	1.000	1	1	0.000	BINARY
Q16:	MapShots	5	1.000	1	1	0.000	BINARY
Q16:	John Deere APEX	28	1.000	1	1	0.000	BINARY
Q16:	SST Summit	1	1.000	1	1		BINARY
Q16:	Spreadsheets (i.e. Microsoft Excel)	22	1.000	1	1	0.000	BINARY
Q16:	Other	2	1.000	1	1	0.000	BINARY

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q16:	Summary - Any Software Used	68	1.000	1	1	0.000	BINARY
Q17:	What age range do you fall in?	107	3.664	1	5	1.220	MULT. CHOICE
Q17.b:	Age Mid-Range	107	51.879	24	65	12.298	SCALE
Q18:	What is your role in the operation you have referenced in this survey?	107	1.355	1	6	1.092	MULT. CHOICE
Q19:	Is there a younger person that is involved with the decision making for the operation?	107	3.075	1	4	1.358	MULT. CHOICE
Q19.a:	No Younger Person Involved in Operation: 51+	114	0.342	0	1	0.477	BINARY
Q19.b:	No Younger Person Involved in Operation: All Ages	114	0.632	0	1	0.485	BINARY
Q20:	How many tillable acres for crop production do you have in your farm operation?	106	1402.132	0	7500	1342.438	FILL-IN
Q20.a:	What percent of your tillable acres are irrigated?	106	70.055	0	100	31.676	FILL-IN
Q20.b:	What percent of your tillable acres are rented?	106	45.257	0	100	34.777	FILL-IN
Q21:	What is your estimated gross farm income for from the 2010 crop year?	106	3.311	1	5	1.260	MULT. CHOICE
Q22.1:	How mange acres of Field Corn did you produce on your operation in 2011?	104	766.916	0	4500	833.653	FILL-IN
Q22.2:	How mange acres of Seed Corn did you produce on your operation in 2011?	104	46.004	0	1700	210.320	FILL-IN

APPENDIX B Continued

NO.	QUESTION	# OF OBS.	MEAN	MIN	MAX	ST. DEV.	TYPE
Q22.3:	How mange acres of Popcorn did you produce on your operation in 2011?	104	7.827	0	414	56.175	FILL-IN
Q22.4:	How mange acres of Soybeans did you produce on your operation in 2011?	104	450.013	0	3500	550.073	FILL-IN
Q22.5:	How mange acres of Wheat did you produce on your operation in 2011?	104	83.760	0	1500	219.886	FILL-IN
Q22.6:	How mange acres of Sorghum (Milo) did you produce on your operation in 2011?	104	10.750	0	600	64.227	FILL-IN
Q22.7:	How mange acres of Alfalfa did you produce on your operation in 2011?	104	23.106	0	340	61.999	FILL-IN
Q22.8:	How mange acres of another crop not previously listed did you produce on your operation in 2011? - Please list the crop and the acres in the single box provided	104	25.779	0	554	96.845	FILL-IN
Q23.1:	What percent of your operation did you use Intensive Tillage on in 2011?	104	5.913	0	100	17.356	FILL-IN
Q23.2:	What percent of your operation did you use Ridge Till on in 2011?	104	25.659	0	100	34.425	FILL-IN
Q23.3:	What percent of your operation did you use Strip-Till on in 2011?	104	2.644	0	90	12.637	FILL-IN
Q23.4:	What percent of your operation did you use Reduced Tillage on in 2011?	104	14.673	0	100	29.713	FILL-IN
Q23.5:	What percent of your operation did you use Continuous No-Till on in 2011?	104	49.736	0	100	40.001	FILL-IN
Q23:	Summary - Conservation Tillage Performed	103	99.583	60	100	3.949	FILL-IN