University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Presentations, Working Papers, and Gray Literature: Agricultural Economics

Agricultural Economics Department

Spring 3-2016

Factors Influencing Producer Propensity for Data Sharing & Opinions Regarding Precision Agriculture and Big Farm Data

Michael H. Castle
University of Nebraska-Lincoln, michael.castle@huskers.unl.edu

Bradley D. Lubben
University of Nebraska-Lincoln, blubben2@unl.edu

Joe D. Luck
University of Nebraska-Lincoln, jluck2@unl.edu

Follow this and additional works at: http://digitalcommons.unl.edu/ageconworkpap

Part of the Agricultural and Resource Economics Commons

Castle, Michael H.; Lubben, Bradley D.; and Luck, Joe D., "Factors Influencing Producer Propensity for Data Sharing & Opinions Regarding Precision Agriculture and Big Farm Data" (2016). *Presentations, Working Papers, and Gray Literature: Agricultural Economics*. 48.
http://digitalcommons.unl.edu/ageconworkpap/48

This Article is brought to you for free and open access by the Agricultural Economics Department at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Presentations, Working Papers, and Gray Literature: Agricultural Economics by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Factors Influencing Producer Propensity for Data Sharing & Opinions Regarding Precision Agriculture and Big Farm Data

Michael H. Castle, Bradley D. Lubben, Joe D. Luck

Abstract: With its tremendous success by notable companies in varying industries, "big data" has become a hard-to-miss phrase and many believe its usage in agriculture is the future of the industry. However, the potential benefits of using big data come with just as many challenges, ranging from not knowing how to make use of it, to the debate over who owns and has access to it. A survey asking for producers' opinions on precision agriculture technologies and big farm data was distributed to a sample of agricultural producers across Nebraska. A Poisson regression was used to determine the factors influencing propensity for data sharing and frequency tables were used to examine producer opinions on the topic. Older producers and those not using irrigation in their operation were found to have a lower propensity for sharing their farm-level data. In general, producer understanding of what big data is and how to use it is lacking. Precision agriculture users mostly believe they have seen increases in profits and efficiency due to use, but producers expressed concern over not knowing how to interpret and make use of the data as well as the overall affordability and cost of the technologies producing the data.

Keywords: Big data, data sharing, policy, precision agriculture, producer opinions

I. Introduction

The modern world is an environment full of rapidly-changing technology, from consumer products, all the way to agricultural production. The agriculture industry has undergone unfathomable changes in the last generation; more information is available to farmers now than ever before. These rapid technological advancements have been driven by an ever-increasing world population and demand for affordable food. To keep up with this demand, precision agriculture technologies aimed at producing more with less are continuously being developed and have shown numerous potential benefits. Usage of these technologies give producers the opportunity to reduce their environmental impacts and improve productivity and profits at the same time (Schieffer and Dillon, 2015). Additionally, many studies have shown these technologies' potential for increasing profitability to producers (Smith et al, 2013; Shockley et al, 2012; Shockley et al, 2011; Mooney et al, 2009; Dillon et al, 2007; Batte and Ehsani, 2006; Griffin et al, 2005). Sonka and Coaldrake (1996) expressed the potential of the linkage between the internet and precision agriculture technologies to alter profoundly agricultural production and marketing systems. Additionally, Paul E. Shickler, president of DuPont Pioneer states: "(w)ith more mouths to feed using less land and fewer resources, the use of on-farm data has the potential to be a game-changer for the world's farmers" (Shickler, 2015). Based on their potential benefits, precision agriculture technology and the "big data" they are capable of producing are considered by many to be the future of agriculture.

Gartner IT Glossary (2013) defines big data as high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation. Gandomi and Haider (2015) discuss the explosion in usage of the term big data in the past five years, and also show a frequency distribution of documents containing the term “big data” in ProQuest Research Library from 2000-2013, which can be seen in the Appendix. Additionally, Sonka (2015) mentions the tremendous media hype of big data, which can be evidenced by the vast amount of articles all over the news discussing the topic, the usage of big data by notable companies, such as Walmart, Coca-Cola, Nestle, McDonald’s, Whole Foods, etc., and big data’s potential as a tool for increasing productivity in farming. However, the usage of this data in agriculture is an entirely new facet for farmers, which could present as many challenges as it does opportunities. Anderson et al (2014) stated the key data challenges relating to big farm data to be: human capital (farmers needing to be tech-savvy), quality data, data access, better data analytics, and agronomic data held by agriculture retailers. Sonka (2015) states that the providers of big data go to great lengths to stress the certainty of the potential of big data as a tool, but the rest of us are much less knowledgeable of the topic and say such things as “Big Data, whatever that is, is going to be important.” This could be a generalization of American farmers as of right now; the understanding of the topic may be lacking, which, if big data is to be the future of the industry, could lead to issues.

Apart from understanding and putting it to use, another issue regarding big farm data is who has access to it and to whom it belongs. Large agribusiness firms Monsanto and Deere & Company are now offering a service that farmers can sign up for, giving them immediate access to farm data as it is produced (Charles, 2014). Many producers are skeptical of these companies causing their data to end up in the wrong hands, and there are countless articles discussing this subject across the news. Singh and Kaskey (2014) state that “big ag companies could now control a data trove that presents privacy and business risks to farmers who don’t want to share the secrets of their trade with rivals or the government.” These concerns regarding security and privacy of data is justified in light of notable recent data breach scandals, such as that with Target, the NSA, and the EPA (Singh and Kaskey, 2014). The overwhelming majority of producers believe farm data belongs to them and them alone (Banham, 2014). Nebraska producers are no exception; a preliminary analysis to this study showed that 100% of 126 respondents from across the state believe that farm data belongs to the farmer (Castle et al, 2015). This belief of ownership has resulted in much discussion of developing a farm data exchange, in which producers could be compensated for sharing of their data (Shickler, 2015; Banham, 2014; Singh & Kaskey, 2014). As such, studying producers’ opinions on data sharing will be of great interest.

Objectives

The purpose of this study is to inform the debate by examining Nebraska row crop producer opinions regarding precision agriculture technology and big farm data. The study will attempt to determine the following:

- If precision agriculture users believe use of the technologies have led to increased profitability.
- Producer understanding of the term “big data.”
- Factors affecting producers’ propensity of sharing their farm data.
- Producers’ main reason for using/not using precision agriculture technologies in their operation.
- What precision agriculture users believe has been the number one benefit of using the technology.
- What producers believe will be the biggest issue regarding advancements in agriculture production technology as well as farm-level data in the future.

As stated above, there has been a great amount of discussion on this topic in recent years. However, most of this discussion comes in news media outlets, not scholarly journals. As such, there has been survey work done on opinions, but no real academic scientific work. To the knowledge of the authors, this is the first study to use academically-accepted econometric methods to examine the factors influencing producers’ propensity to share their farm-level data.

II. Methodology

Data Collection

In order to analyze producer opinions, a survey was developed to distribute to row crop farmers in Nebraska. The survey is broken down into three sections: Demographic & Farming Operation Information, Technology Usage, and Opinions on Technology and Data. The first section asks for information such as operator age, experience, county of operation, acres in operation, crops produced, average yields, production practices, income/cost information, etc. The second section was the focus of the first analysis of this project, as it asks farmers’ use of specific precision agriculture technologies and for which operations they are using them. The focus of this study is the third section, as it covers producers’ opinions on precision agriculture technology and issues relating to farm-level data. A copy of the survey used can be found in the appendix. Not all questions asked in this survey were part of the analysis of this study, as this study is a continuation of a project from the previous year, in which overall adoption and opinions of precision agriculture technology in the state of Nebraska were examined.

Surveys were distributed at several different Nebraska Extension sponsored events across the state during 2014-15. These events included Nebraska Extension Crop Production Clinics across the state, Nebraska Extension Precision Ag Data Management Workshops, the 2015 Fremont Corn Expo (sponsored by Nebraska Extension), and the 2015 NEATA Ag Technology Conference. In total, 135 responses were received. However, these responses had to be narrowed down to eliminate out-of-state responses and those with missing data. The questions from the “Opinions on Technology and Data” section analyzed were questions one, three, four, six, seven, eight, and nine. These questions had 93, 91, 89, 72, 69, 66, and 53 usable responses, respectively. Although the sample size is smaller than desired, the data produced still provide worthwhile insight into real producer opinions on this pressing issue.

An additional note about the sample: due to the fact that surveys were distributed at various Nebraska Extension events, it is not a true random sample, and respondents are most likely more progressive than the average farmer in the state. As such, they most likely have a better understanding of the topic of “big data” than a true random sample of producers across the state as well as most likely having a higher rate of adoption of precision agriculture technologies in their operations.

Development of the Variables

The first variable requiring some development was the profit belief index. Question 1 gave respondents three options when asking whether or not they believe profits have increased due to usage of precision agriculture technology: yes, no, or uncertain. In setting up the index, “yes” was given a value of 1, “uncertain” a value of 0, and “no” a value of -1. Thus, a positive index value indicates more respondents believe the technologies have increased profits, while a negative index value indicates respondents do not believe the technologies have increased profits.

The next index to be developed was for producers’ understanding of the term “big data.” Question 3 of the opinions section was a level of agreement question (strongly agree, somewhat agree, somewhat disagree, strongly disagree) asking whether or not respondents agree with the statement “I fully understand the term ‘big data.’” As such, the understanding index is essentially a Likert scale, with strongly disagree given a value of 1, somewhat disagree given a value of 2, somewhat agree a value of 3, and strongly agree a value of 4. So, a higher value of the understanding index would indicate producers having a higher understanding of the term “big data,” while a lower value of the index would indicate a lesser understanding of the term.

In order to perform the regression on producers’ propensity of data sharing, some of the categorical data had to be turned into empirical data. In total, five different factors influencing producers’ propensity of sharing their data were examined.

The first factor potentially affecting producers’ willingness to share their farm data analyzed in this study was operator age. The first question of the survey asked for producers’ age by having them indicate one of six ranges of ages (≤25, 25-34, 35-44, 45-54, 55-64, 65+). These categorical variables had to be turned into empirical variables in order to perform a regression between age and the data sharing index that would produce an equation in which age could be used as a predictor of number of institutions with which each producer is comfortable sharing their data. To make the categorical age range options into empirical variables for analysis, the age values are assumed to be the midpoint of the range. However, the two end ranges (≤25 and 65+) are open ranges and thus do not have an endpoint. For purposes of this study, the assumption is made that no one under the age of 18 responded to this survey as the principal operator of the farming operation in which they are involved. Thus, the range for option (a) becomes 18-25 and the midpoint age used is 21.5. For the 65+ option, the age range is assumed to be 65-74, in order to keep consistency with the other age ranges and thus the midpoint age used for option (f) is 69.5.

The second independent variable studied was the number of row crop acres in the producer's operation (i.e. size of operation). Question 4 asked respondents to report the number of row crop acres that they farm. This data was empirical and continuous, allowing it to be easily regressed against the data sharing index.

The third independent variable studied was each producers' technology adoption index, essentially the number of precision agriculture technologies adopted. This index comes from the previous study and ranges from 0 to 7. The seven technologies included in this index are cell phone with internet access, GPS guidance, autosteer, variable-rate application technology, automatic section control, yield monitors, and prescription maps. The questions in the survey regarding usage of a cell phone with internet access, GPS guidance, yield monitors, and prescription maps were simple yes or no questions, so users were counted simply as those who responded "yes", allowing users of the technologies to be given a value of 1, while those who responded "no" were identified as non-users and given a value of 0. On the other hand, the questions regarding usage of autosteer, variable-rate technology, and automatic section control asked respondents if they used the technology for a given list of operations and to circle all operations for which they used said technology. So, in order to turn these responses into users and non-users, those who chose the option "I don't use (respective technology)" were identified as non-users and given a value of 0, and those who reported using the technology for at least one operation were identified as users and given a value of 1. Finally, these 1s and 0s are summed in order to create the index ranging from 0 to 7.

The final two independent variables analyzed were use of irrigation in the operation and whether or not the producer owns a cell phone with internet access (i.e. a smart phone). Both of these variables are binomial; their values are either a 0 or a 1. In the case of irrigation use, question 7 of the Demographic and Farming Operation Information section asked respondents to report how many acres are in production for each of the following crops: irrigated corn, dryland corn, irrigated soybeans, dryland soybeans, wheat, and other. Those who reported having any acres in irrigated row crop production were given a value of 1 and those who reported only having acres in dryland row crop production were given a value of 0. For the use of a cell phone with internet access, question 2 of the Technology Usage section asks a simple yes or no question as to whether or not the respondent has a cell phone with internet access. So, respondents who reported "yes" are given a value of 1 and those who reported "no" are given a value of 0.

In order to determine the propensity of producers to share their farm-level data, an index of the number of institutions with which the producer feels comfortable sharing their data was developed. The index is essentially the number of institutions that producers indicated they feel comfortable sharing their data. There were seven available choices to the question: no one, relatives, neighbors, equipment dealers, local co-op, university researchers or educators, and the company who manufactured the equipment. The index values range from 0 to 6, with 0 meaning the producer feels comfortable sharing their with no one and 6 meaning the producer feels comfortable sharing their farm data with all 6 of the institutions in question.

After manipulation, the result is five numerical independent variables as a predictor of the number of institutions with which producers feel comfortable sharing their farm data, with higher values indicating a greater propensity for sharing and lower values indicating a lesser propensity for data sharing.

Modeling Propensity for Data Sharing

In this study, the goal was to analyze the effects of four independent variables on one dependent count variable. To accomplish this goal, a Poisson model with a log link function was used to analyze the effects of age, row crop acres, technology adoption index, and use of irrigation on the number of institutions with which the producer feels comfortable sharing their farm data. This is the same approach used in our previous study on the factors influencing adoption of precision agriculture technologies, in which similar independent variables were regressed against the number of precision agriculture technologies adopted by the producer. This method has been accepted in other relevant literature in the field, such as in a study by Paxton et al (2010) in which factors affecting the number of technologies adopted by cotton producers in the Southeastern U.S. were analyzed. Their study used both a Poisson model and a negative binomial model in order to study the effects of different characteristics on the number of precision agriculture technologies being used by producers, but this study will only use the Poisson, as the negative binomial model is more suited for use when the dependent variable frequently takes on a value of zero. As such, the negative binomial model is not as useful for this study. Paxton et al (2010) also noted that this method has been employed previously in multiple disciplines, such as patent literature.

In this study, the number of institutions with which the producer *i* feels comfortable sharing their farm-level data (D_i) can be expressed as a function of four independent variables (X_i) as follows:

$$\ln(D_i) = \propto \, + \beta_i X_i \tag{1}$$

Thus,

$$D_i = \, e^{\propto \, + \, \beta_i X_i} \tag{2}$$

Where α is the intercept and β_i are the respective parameter estimates for each variable produced by SAS in running the Poisson regression. To determine the marginal effect of each variable, function (2) must be differentiated with respect to the independent variable, X_i, yielding:

$$\frac{dD_i}{dX_i} = \beta_i e^{\propto \, + \, \beta_i X_i} \tag{3}$$

From equation (3), it can be seen that the sign of the parameter estimate, β_i, indicates the sign of the marginal effect of each respective variable. For further explanation of the Poisson model, please view the study by Paxton et al (2010), given in the References section.

III. Results and Discussion

As discussed above, there were a total of 135 responses received, but after accounting for missing data, there were 93, 91, 89, 72, 69, 66, and 53 responses used in analysis for questions one, three, four, six, seven, eight, and nine, respectively. A summary table of the results of question one can be seen below.

Table 1.

Believe Profits Have Increased from Use?		
Answer	**Observations**	**Percentage**
Yes	65	69.89%
Uncertain	23	24.73%
No	5	5.38%
Average Profit Belief Index (ranging from -1 to 1)	0.65	
Average Number of Techs Adopted	4.80	

As can be seen in table 1 above, nearly 70% of precision agriculture technology users believe that their profits have increased due to the usage of the technologies. This belief would be consistent with the conclusions of a multitude of studies showing the potential for increases in profitability from the use of various specific precision agriculture technologies (Smith et al, 2013; Shockley et al, 2012; Shockley et al, 2011; Mooney et al, 2009; Dillon et al, 2007; Batte and Ehsani, 2006; Griffin et al, 2005). It is also noteworthy that only slightly over 5% of respondents believe their profits have not increased due to use of the technologies, while the remaining approximately 25% reported they were uncertain as to whether or not the technologies have increased their profits. This uncertainty is also consistent with other relevant literature; although many studies have shown precision agriculture technologies' potential for increasing profits, there have been no studies examining whether or not this potential has been realized among users and there have also been studies that have shown mixed or even negative returns (Boyer et al, 2011; Daberkow & McBride 2003). The average profit belief index shown in the table was 0.65, indicating that many more users believe the technologies have increased their profits than not. The final number in the table shows that the average number of precision agriculture technologies being used by respondents to question 1 was 4.8 of the 6 technologies studied. So, for the most part, these are producers using a large amount of available precision agriculture technologies, not just a few of them. This relatively high number of technologies adopted may be a factor influencing producers' profit belief.

The next question examined producers' understanding of the term "big data," a term that brings with it a vast amount of discussion and hype, as discussed above. A summary of the results from question 3 of the opinions section is shown below in Table 2.

Table 2.

Understanding Level	Observations	Percentage of Respondents
Strongly Disagree	11	12.1%
Somewhat Disagree	22	24.2%
Somewhat Agree	43	47.3%
Strongly Agree	15	16.5%
Average Understanding Index	2.68	

As can be seen in Table 2, the average understanding index of the respondents to question 3 was 2.68. This indicates that the average response was between somewhat disagree and somewhat agree, closer to somewhat agree (which was the most common response at just over 47%). Over 36% of respondents reported that they either strongly or somewhat disagree with the statement, and only 16.5% stated that they strongly agree, which could prove to be an issue in the future as the usage of big farm data is expected to eventually be of great importance to the industry. As such, producers' understanding of the topic will be crucial, not just in being able to put the data to use in order to increase productivity/efficiency, but also in understanding their rights in terms of ownership and sharing of their data.

The next question examined with whom the producers feel comfortable sharing their farm data. A summary table of the results to the question can be seen below in Table 3.

Table 3.

With Whom do you Feel Comfortable Sharing your Farm Data?		
Choice	**Observations**	**Percentage of Respondents**
University Researchers or Educators	39	43.82%
Local Co-op	38	42.70%
Relatives	33	37.08%
No one	20	22.47%
Equipment Dealers	18	20.22%
Company who Manufactured the Equipment	17	19.10%
Neighbors	12	13.48%
Average Sharing Index (Scale of 0-6)	1.76	

As can be seen in Table 3, the average sharing index was 1.76, meaning that the average respondent feels comfortable sharing their farm data with less than two of the six institutions in question. So, in general, the respondents do not feel comfortable sharing their farm data with others, which is consistent with the overall discussion of the topic. The institution that the highest amount of producers feel comfortable sharing their data with was university researchers or educators, most likely due to the fact that those associated with the university are typically not interested in the data for monetary purposes, as more likely would be private industry firms, but rather for purposes of study and education. Additionally, the survey was distributed to producers at Nebraska Extension events, so they obviously have a positive enough opinion of the University just to be in attendance. Neighbors was the response with the least observations, meaning producers are very concerned with their data going to their competitors. Neighbors was preceded by the company who manufactured the equipment and equipment dealers. This result is very consistent with relevant discussion of the topic, as Singh and Kaskey (2014) discussed farmers' concern over their data being given to big agriculture companies and their rivals. It's also noteworthy to point out that more producers stated they feel comfortable sharing their farm data with no one than with equipment dealers, equipment manufacturing companies, and their neighbors. These results provide numerical evidence as to the overall lack of comfort in sharing farm data by producers in the state.

After examining the overall results of the question, the Poisson regression was performed in order to determine the factors influencing producers' propensity of sharing their data. The results of the Poisson regression are shown below in Table 4.

Table 4.

Variable	Poisson Model Parameter Estimate[1]	Standard Error	P-Value
Intercept	1.7518***	0.3754	0.0000***
Acres	0.0000	0.0001	0.5857
Age	-0.0158***	0.0055	0.0042***
Tech Adoption Index	-0.0598	0.0468	0.2013
Non-Irrigator	-0.3615**	0.1831	0.0484**

[1]Significance at the 10%, 5%, and 1% level are indicated by one, two, and three asterisks, respectively.

Table 4 above shows the parameter estimates for each respective variable. As can be seen, the number of row crop acres in the operation is estimated to have no effect on the propensity to share farm data. This result suggests that the size of operation does not provide much explanatory power in a producer's comfort in sharing, which may be skewed due to the fact that acres and technology adoption index have a statistically significant relationship. Operator age was found to have a negative and statistically significant (at the 1% level) effect on propensity for sharing farm data, meaning that the older the producer, the lower the willingness to share their data. This result makes sense, as older generations are generally less tech-savvy and more skeptical of newer technologies. The technology adoption index resulted in a negative parameter estimate, but the result was not statistically significant. This negative parameter estimate means that producers using more technologies have a lower propensity for sharing their data, which may be because these producers have a greater familiarity with the risks of their data falling into the wrong hands due to their greater exposure to the topic. The final factor was the usage of irrigation in the operation. Non-irrigators were found to have a lesser propensity to share their farm data than those using irrigation, as shown by the negative parameter estimate that was also statistically significant at the 5% level.

The final four questions examined were open-ended questions asking producers their opinions. The first open-ended question asked producers their main reason for using/not using precision agriculture technologies in their operation. A summary of the responses can be seen below in Table 5.

Table 5.

Reason	Observations	Percentage of Respondents
For Using		
Increase Efficiency	16	22.22%
Reduce Inputs & Input Cost	15	20.83%
Increase Productivity & Profits	11	15.28%
Reduce Fatigue/Operator Convenience/Ease of Operation	9	12.50%
Documentation/Recordkeeping	6	8.33%
Benefit the Environment	3	4.17%
Improve Accuracy	3	4.17%
For Not Using		
Cost of Investment	11	15.28%
Size of Operation (too small to justify)	5	6.94%
Uncertain ROI/Paying for Itself	3	4.17%
Difficulty with Using/Learning new Technology	2	2.78%
Close to Retirement or Farm Transition	2	2.78%
Other*	4	5.56%

*4 of the 72 responses did not fall into a category and were thus categorized as "other."

As can be seen in the table, the number one reason reported for using precision agriculture technologies was to increase efficiency, followed very closely by the extremely similar response of reducing inputs and input cost, then increasing productivity and profits. This reasoning for use is consistent with several studies that have shown specific precision agriculture technologies to have the ability to increase efficiency and reduce inputs, thus increasing profits (Smith et al, 2013; Shockley et al, 2013; Shockley et al, 2011; Dillon et al, 2007; Batte and Ehsani, 2006). Some of the additional responses, such as reducing fatigue/operator convenience/ease of operation and benefitting the environment have also been shown in the relevant literature (Schieffer and Dillon, 2015; Griffin et al, 2005; Zilberman et al, 1997). The top reasons for not using precision agriculture technologies were the cost of investment and the size of operation (too small to justify, which relates directly to cost). This result makes sense, as the potential benefits of these technologies do come at an increased cost, so some producers simply may not be able to afford the technologies and others are likely skeptical of the value of the technology.

The next open-ended question analyzed asked users of the technologies what they believe has been the number one benefit. A summary of the responses are shown below in Table 6.

Table 6.

Response	Observations	Percentage of Respondents
Reduced Inputs/Input Cost	22	31.88%
Improved Accuracy/Quality of Field Work	10	14.49%
Operator Ease/Reduced Fatigue/Able to put in Longer Hours	10	14.49%
Increased Information and Data Available/Recordkeeping	9	13.04%
Increased Efficiency	8	11.59%
Increased Yields	8	11.59%
Greater Productivity/Profits	3	4.35%
Improved Management	2	2.90%
Able to See & Control Variability in Field	2	2.90%
Other*	11	15.94%

*11 of the 69 responses did not fall into a category and were thus categorized as "other."

As can be seen in Table 6, by far the most common response as the number one benefit received was reduced inputs/input cost, which is consistent with the relevant literature in the discussion of the results of the prior question. Tied for second were improved accuracy/quality of field work, along with operator ease/reduced fatigue/able to put in longer hours, which is also consistent with the studies noted in the discussion of the last question as well. As shown, there is a good amount of variation amongst the benefits listed; benefits in recordkeeping and management, increased efficiency, yields, and profits, controlling variability in the field, and helping the environment. So, it's obvious from the results of this question that users believe there is a wider range of benefits from usage of the technology than the reasons that have been previously studied.

The third open-ended question asked producers what they think will be the biggest issue regarding advancements in agricultural production technology in the future. A summary of responses are as follows in Table 7.

Table 7.

Response	Observations	Percentage of Respondents
Affordability and Cost	22	33.33%
Interpreting/Making Sense of & Using the Data	7	10.61%
Return on Investment	6	9.09%
Reliability of Technology/Tech Support Issues	6	9.09%
Increasing Production, Profits, Yields	4	6.06%
Government Regulations	4	6.06%
Keeping up With/Learning New Technologies	4	6.06%
Older Generation Not Wanting to Use	4	6.06%
Data Security/Confidentiality	2	3.03%
Ownership of Data	1	1.52%
Conserving Resources/Helping Environment	1	1.52%
Education	1	1.52%

As seen in the above table, affordability and cost was the overwhelming most common response, with one-third of respondents stating something in this category. This result is consistent with the number one reason for not adopting precision agriculture, found and discussed above in Table 5. Additionally, our prior study on the factors influencing adoption showed that number of row crop acres in the operation was found to be a significant factor, with larger operations adopting more of the technologies, in large part because larger operations are much more able to afford the technologies. The second-most popular response concerned the interpretation and use of the data produced by the technologies, which will be discussed further in the next question, as well as the other two response categories relating to data. The rest of the responses are widely varied, with some concerns regarding the economics of the technologies, some with issues using the technologies, others with concerns over regulations, etc.

The final open-ended question examined in the study asked producers what they believe will be the biggest issue regarding farm-level data generated from precision agriculture technologies. As discussed earlier, issues surrounding “big data” in agriculture are of great relevance today. A summary of the results to the question are shown below in Table 8.

Table 8.

Response	Observations	Percentage of Respondents
Understanding How to Use/Interpret Data	23	43.40%
Data Security/Confidentiality/Who has Access to it	14	26.42%
Ownership of Data	5	9.43%
Accuracy of Data	4	7.55%
Return on Investment	3	5.66%
Glitches/Missing Data/Technical Problems	2	3.77%
Compatibility Issues	2	3.77%
Cost of Equipment & Software	1	1.89%

This question is of great relevance due to the importance of the topic. Sonka (2015) notes that IBM (2015) forecasts that the data that exists in the world today will be doubled in two years, which will present challenges never experienced before. As seen above, respondents believe the number one issue regarding farm-level data generated by precision agriculture technologies is understanding how to use/interpret the data. This makes sense due to the fact that data analytics in agriculture is such a new field that most producers don't have a great deal of experience with it. Additionally, other recent articles have discussed this issue of farmers needing to learn more regarding how to properly use this data (Sonka, 2015; Anderson et al, 2014). Furthermore, Table 2 shows that a large amount of producers do not understand the topic, and a relatively small amount strongly agree that they fully understand the term, which will most likely have vast implications in the future. The next two most common responses (data security/confidentiality/access and ownership of data) are closely related and also a very noteworthy finding. Again as noted in the introduction, there is a vast amount of discussion and articles on this topic circulating throughout the news. Notable articles discussing the ownership of farm data have stated the opinion that farm data should belong to the farmer and that they should be in control of who it is shared with and compensated for doing so (Castle et al, 2015; Schickler, 2015; Banham, 2014; Singh and Kaskey, 2014). The results of this study further this in showing the large amount of concern being expressed by producers. However, it is also worth noting that more producers stated they were concerned with interpreting and using the data than those who stated they are concerned with issues regarding the security, confidentiality, and ownership of the data.

IV. Conclusions

This study examined producers' opinions regarding precision agriculture technologies and big agricultural data. It also studied the factors influencing producers' propensity for sharing their farm data. Summary data and a Poisson regression model were used to study these topics using data collected from a survey distributed across the state of Nebraska at Extension events during 2014-2015. This study contributes to the literature by producing the first scientific work on the factors influencing producers' comfort in data sharing and also provides a new empirical result on actual producer opinions on a multitude of relevant questions on the topic.

In terms of the factors influencing propensity to share farm data, two of the four factors studied were found to be statistically significant: operator age and irrigation use. The results allow us to conclude that older producers have a lower propensity to share their data than do younger producers, most likely due to the older generation being more skeptical of and less familiar with the new technologies. Producers not using irrigation in their operation were found to have a lower propensity to share their data, which could be due to their lower intensity of production and thus lesser reliance on data for efficiency. Although not statistically significant, it is of interest that the more tech-savvy producers (those using a cell phone with internet access and a higher number of precision agriculture technologies in their operation) had a lower propensity to share their data, potentially due to their greater understanding of the issue.

Simple survey work on producer opinions on the topic were also studied. The survey results allow us to conclude that the majority of precision agriculture users believe their profits have increased due to use of the technologies, which would be consistent with many of the studies addressing the potential for increased profitability from use, as mentioned above. Additionally, the study examined producers' understanding of the term "big data" and allows us to conclude that producer understanding of the topic is lacking, with only a small amount fully understanding the term, which could prove to be an issue in the future. The highest number of producers were comfortable sharing their data with university researchers and educators, while they were least comfortable sharing with neighbors. More respondents reported they were comfortable sharing their farm data with no one than with equipment dealers, manufacturers, and neighbors. From the open-ended questions, the number one reason for using precision agriculture technologies was to increase efficiency, while the number one reason for not using was the cost of the investment. The most common number one benefit reported by respondents was reduced inputs and input cost. Regarding the future of the industry, the most common response for the biggest issue regarding advancements in agricultural production technology was affordability and cost of the technologies, and the biggest issue concerning farm-level data was understanding how to use and interpret the data.

The results of this study have implications for producers, precision agriculture equipment dealers and manufacturers, large agribusiness firms interested in use of farm data, Extension educators, and agricultural policy makers. Due to the fact that age is the most significant negative factor on propensity to share data, the impending large turnover in farmers due to the current age makeup in the industry may have large impacts on the sharing of farm data. It is obvious that "big data" has a large potential for benefitting the industry, but comes with many complications that policy makers will need to address. Producers do not currently have the level of understanding needed to both put the data to use and to ensure the ownership and security of their data. Thus, it is imperative to improve producer education on the topic.

V. References

Anderson, E., M. Darr, K. Heckert, B. Jones, D. Lemke, D. Miller. "The Digital Transformation of Row Crop agriculture." A "Big Data" Project Report for the Iowa AgState Group, December 2014. Retrieved November 21, 2015 from https://www.iowafarmbureau.com/page/file?path=Files%2Fwebsite%2FNews%2FPDFs%2Fagesmed.pdf.

Banham, R. "Who Owns Farmers' Big Data?" *Forbes* (2014). Retrieved November 21, 2015 from http://www.forbes.com/sites/emc/2014/07/08/who-owns-farmers-big-data/.

Batte, M.T., and M.R. Ehsani. "The Economics of Precision Guidance with Auto-Boom Control for Farmer-Owned Agricultural Sprayers." *Computers and Electronics in Agriculture* 53 (2006): 28-44.

Boyer, C.N., B.W. Brorsen, J.B. Solie, W.R. Raun. "Profitability of Variable Rate Nitrogen Application in Wheat Production." *Precision Agriculture* 12 (2011): 473-487.

Castle, M, B. Lubben, J. Luck. "Precision Agriculture Usage and Big Agriculture Data." *Cornhusker Economics* (2015). Retrieved November 26, 2015 from http://agecon.unl.edu/cornhusker-economics-may-27-2015.

Charles, D. "Should Farmers Give John Deere and Monsanto Their Data?" *The Salt* (2014), NPR Newscast. Retrieved on November 26, 2015 from http://www.npr.org/sections/thesalt/2014/01/21/264577744/should-farmers-give-john-deere-and-monsanto-their-data.

Daberkow, S., W. McBride, M. Ali (2003). "Implications of Remote Sensing Imagery and Crop Rotation for Nitrogen Management in Sugar Beet Production." Paper presented at the Agricultural and Applied Economics Association meeting, Montreal, Canada, July 27-30. Retrieved November 7, 2015 from http://ageconsearch.umn.edu/bitstream/22052/1/sp03da01.pdf.

Dillon, C.R., S. Shearer, S. Pitla. "Improved Profitability via Enhanced Variable Rate Application Management Resolution in Grain Crop Production." *Proceedings of the 6th European Conference on Precision Agriculture* (2007): 819-825. Wageningen Academic Publishers.

Gartner IT Glossary. (2012). *Big Data*. Retrieved November 21, 2015 from http://www.gartner.com/it-glossary/big-data.

Gandomi, A. and M. Haider. "Beyond the Hype: Big Data Concepts, Methods, and Analytics." *International Journal of Information Management* 35 (2015): 137-144.

Gerlock, G. "Farmers Worry About Sharing Big Data." *Harvest Public Media* (2014). Retrieved November 21, 2015 from http://harvestpublicmedia.org/article/farmers-worry-about-sharing-big-data.

Griffin, T.W., D.M. Lambert, J. Lowenberg-DeBoer. “Economics of Lightbar and Auto-Guidance GPS Navigation Technologies.” Precision Agriculture Refereed Conference Proceedings (2005): 581-587.

Mooney, D.F., R.K. Roberts, J.A. Larson, B.C. English (2009). “Economics of the Variable Rate Technology Investment Decision for Agricultural Sprayers.” Paper presented at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, January 31-February 3. Retrieved November 7, 2015 from http://ageconsearch.umn.edu/handle/46860.

Schieffer, J. & C. Dillon. “The Economic and Environmental Impacts of Precision Agriculture and Interaction with Agro-Environmental Policy.” *Precision Agriculture* 16 (2015): 46-61.

Shickler, P. E. “Opinion: Keeping Farmers in the Driver’s Sear with Their Farm Data.” *Agri-Pulse* (2015). Retrieved on November 21, 2015 from http://www.agri-pulse.com/Opinion-Keeping-farmers-in-the-drivers-seat-with-their-farm-data-12292014.asp.

Shockley, J.M., C.R. Dillon, T.S. Stombaugh. “A Whole Farm Analysis of the Influence of Auto-Steer Navigation on Net Returns, Risk, and Production Practices.” *Journal of Agricultural and Applied Economics* 43(1) (2011): 57-75.

Shockley, J., C.R. Dillon, T. Stombaugh, S. Shearer. “Whole Farm Analysis of Automatic Section Control for Agricultural Machinery.” *Precision Agriculture* 13 (2012): 411-420.

Singh, S. & J. Kaskey. “Farmers Press Agribusiness Giants for Data Security.” *Bloomberg Business* (2014). Retrieved on November 21, 2015 from http://www.bloomberg.com/bw/articles/2014-01-23/farmers-press-agribusiness-giants-for-data-security.

Smith, C.M., K.C. Dhuyvetter, T.L. Kastens, D.L. Kastens, L.M. Smith. “Economics of Precision Agricultural Technologies Across the Great Plains.” *2013 Journal of the ASFMRA* (2013).

Sonka, S. “Big Data: From Hype to Agricultural Tool.” *Farm Policy Journal* (2015).

Sonka, S., and Y.-T., Cheng. "Big Data in Farming: Why Matters!" *farmdoc daily* (5):211, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, November 12, 2015.

Sonka, S., and Y.-T., Cheng. "Big Data: More Than a Lot of Numbers!" *farmdoc daily* (5):201, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, October 29, 2015.

Sonka, S. T. and K. F. Coaldrake. “Cyberfarm: What Does it Look like? What Does it Mean?” *American Journal of Agricultural Economics* 78(5) (1996): 1263-1268.

Sonka, S., and Y.-T., Cheng. "Precision Agriculture: Not the Same as Big Data But..." *farmdoc daily* (5):206, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, November 5, 2015.

Tey, Y.S. & M. Brindal. “Factors Influencing the Adoption of Precision Agricultural Technologies: A Review for Policy Implications.” *Precision Agriculture* 13 (2012): 713-730.

Walton, J.C., D.M. Lambert, R.K. Roberts, J.A. Larson, B.C. English, S.L. Larkin, S.W. Martin, M.C. Marra, K.W. Paxton, J.M. Reeves. “Adoption and Abandonment of Precision Soil Sampling in Cotton Production.” *Journal of Agricultural and Resource Economics* 33(3) (2008): 428-448.

Watcharaanantapong, P., R.K. Roberts, D.M. Lambert, J.A. Larson, M. Velandia, B.C. English, R.M. Rejesus, C. Wang. “Timing of Precision Agriculture Technology Adoption in US Cotton Production.” *Precision Agriculture* 15 (2014): 427-446.

Zilberman, D., M. Khanna, L. Lipper. “Economics of New Technologies for Sustainable Agriculture.” *The Australian Journal of Agricultural and Resource Economics* 41(1) (1997): 63-80.

VI. Appendix

Precision Ag Usage and Benefits in Nebraska

This survey is asking for information about you and your farming operation regarding your usage and opinions of precision agriculture technologies. Your responses to this survey are very important and will provide an understanding of current adoption and benefits of agricultural technologies. The results will be made available to the public, which may help producers like you make better decisions regarding technology usage. Plus, your opinions will provide valuable information regarding policy issues surrounding farm data—a key issue of the future of agriculture.

Your response to this survey is voluntary and completely confidential. Researchers will not have access to information identifying participants. Your decision whether or not to participate in this survey will not affect your relationship with the University of Nebraska-Lincoln in any way. Completion of this survey implies your consent to participate in this research project, while not completing this survey implies that you do not consent to participating. With this in mind, please be as honest as possible when answering the following questions. The survey should take approximately 10-20 minutes to complete.

This project is funded through a grant from the Undergraduate Creative Activity and Research Experience (UCARE) program at the University of Nebraska-Lincoln.

We thank you in advance for your commitment of time to complete this survey.

Sincerely,

Michael H. Castle
Undergraduate Research Assistant
Department of Agricultural Economics

Dr. Bradley D. Lubben
Extension Policy Specialist
Department of Agricultural Economics

Demographic & Farming Operation Information

1. How old are you?
   a. ≤ 25 b. 25-34 c. 35-44 d. 45-54 e. 55-64 f. 65+
2. How many years have you been farming?
   a. Less than 5 b. 5-14 c. 15-24 d. 25-34 e. 35-49 f. 50+
3. In what county is the **majority** of the land in your operation located?

   ____

4. How many row crop acres do you farm?

   ____

5. How many total acres are in your operation?

   ____

6. Please report the **percentage** of acres in your row crop operation in each of the following categories.
   a. Owned by you ________________
   b. Cash rented from someone else ________________
   c. Crop share leased from someone else ________________
   d. Custom farmed for someone else ________________
7. In your operation, how many acres are in production for each of the following crops?
   a. Irrigated Corn ________________
   b. Dryland Corn ________________
   c. Irrigated Soybeans ________________
   d. Dryland Soybeans ________________
   e. Wheat ________________
   f. Other ________________
8. What are your average yields (in Bushels/Acre) for the following crops?
   a. Irrigated Corn ________________
   b. Dryland Corn ________________
   c. Irrigated Soybeans ________________
   d. Dryland Soybeans ________________
   e. Wheat ________________
   f. Other ________________
9. What types of cropping systems do you use? (Circle all that apply)
   a. Continuous corn
   b. Corn/Soybean rotation
   c. Corn/Soybean/Wheat rotation
   d. Other ________________________________

10. What tillage practices do you use in your operation? (Circle all that apply)
    a. Intensive Tillage (Less than 15% residue)
    b. Reduced Tillage (15-30% residue)
    c. Conservation Tillage (Greater than 30% residue)
    d. No-till

    Which one of these tillage practices do you use on the most acres in your operation?

    ____

11. What is your average yearly **gross** farm income?

    a. < $250,000   b. $250,000-$749,999   c. $750,000-$1,499,999
    d. $1,500,000-$2,500,000   e. $2,500,000-$5,000,000   f. $5,000,000+

12. In the past year, what was your average production cost per acre for each of the following crops? OR, if not applicable for each crop, what was your overall average production cost per row crop acre?
    a. Irrigated Corn ______________
    b. Dryland Corn ______________
    c. Irrigated Soybeans ______________
    d. Dryland Soybeans ______________
    e. Wheat ______________
    f. Other ______________
    AND / OR
    g. Overall Average Production Cost per Acre ______________

13. In the past year, what was your total profit per acre for each crop? OR, if not applicable for each crop, what was your overall total profit per row crop acre?
    a. Irrigated Corn ______________
    b. Dryland Corn ______________
    c. Irrigated Soybeans ______________
    d. Dryland Soybeans ______________
    e. Wheat ______________
    f. Other ______________
    AND / OR
    g. Overall Total Profit per Acre ______________

Technology Usage

1. Do you have a computer with access to high-speed broadband internet?
   a. Yes b. No

   If yes, where is it located?

   a. Home b. Farm Office c. Both

2. Do you have a cell phone with internet access?

   a. Yes b. No

3. In your farming operation, do you use any GPS guidance systems?
   a. Yes b. No

   If yes, what type of GPS signal system do you use?

   a. RTK (own base station) b. RTK (service provided by dealer)

   c. DGPS d. WAAS

   e. I use GPS but don't know the details

Which of the following displays do you use?

a. Light bar b. Visual screen (LCD or computer screen) c. Both

For which operations do you use GPS guidance? (Circle all that apply)

a. Tillage b. Fertilizer Application c. Planting d. Spraying e. Harvesting

4. Do you use autosteer for any of the following operations? (Circle all that apply)
   a. Tillage
   b. Fertilizer Application
   c. Planting
   d. Spraying
   e. Harvesting
   f. I don't use autosteer
5. Do you use variable-rate application for any of the following? (Circle all that apply)
   a. Planting
   b. Irrigation
   c. Lime
   d. Nitrogen
   e. P or K
   f. I don't use variable-rate application
6. Do you use automatic section control to automatically turn boom sections and/or planter units on or off for any of the following operations? (Circle all that apply)
   a. Planting
   b. Spraying
   c. Harvesting
   d. Dry Fertilizer Application
   e. Liquid Fertilizer Application
   f. I don't use automatic section control
7. Do you use any kind of satellite/aerial imagery to monitor crop progress and/or make agronomic decisions?
   a. Yes b. No
8. Do you use any chlorophyll/greenness sensors to monitor crop progress and/or make agronomic decisions?
   a. Yes b. No

9. Do you use any soil sampling in your operation?
   a. Yes b. No

   If yes, what type of sampling do you do? (Circle all that apply)

   a. Composite
   b. Zone
   c. Grid

10. Do you use a yield monitor?
    a. Yes b. No

    If yes, do you use it with GPS in order to generate yield maps?
    a. Yes b. No

11. Do you, or anyone in your operation, personally manage your operation's farm data?
    a. Yes b. No

    If no, who manages your farm data?

    a. Equipment Dealer b. Co-op c. Consultant d. Other ________________

12. Do you use any prescription maps for your operation?
    a. Yes b. No

    If yes, where are the maps generated?

    a. Use the software yourself to create prescription maps
    b. Use a consultant that doesn't sell application products
    c. Use a dealership or co-op that also sells application products
    d. Other ____

13. If you create your own prescription maps for variable-rate application, what software do you use? ____

14. Which operations do you use this software to manage? (Circle all that apply)

    a. Yield mapping
    b. Record keeping
    c. Variable-rate application of nutrients or fertilizer
    d. Variable-rate seeding or planting
    e. Boundary mapping
    f. Soil sampling and testing
    g. I don't use the software for any of these
    h. Other _______________________________

15. How do you transfer your data from the field to your computer? (Circle all that apply)

    a. Wirelessly through wi-fi connection
    b. Wirelessly through cellular modem
    c. Using an external flash drive/jump drive or memory card

Opinions on Technology and Data

1. Overall, would you say your profits have increased due to using precision ag equipment?

   a. Yes b. No c. Uncertain

   If yes, would you say it is **more** due to:

   a. A decrease in input costs because of increased efficiency
   b. An increase in total production

2. Considering the additional costs of purchasing the technology and also its performance, would you say the investment in precision ag equipment was worth it?

   a. Yes b. No

3. Do you agree with the following statement, "I fully understand the term 'Big Data'"?

   a. Strongly agree b. Somewhat agree c. Somewhat disagree d. Strongly disagree

4. With whom do you feel comfortable sharing your farm data? (Circle all that apply)
   a. No one
   b. Relatives
   c. Neighbors
   d. Equipment dealers
   e. Local Co-op
   f. University Researchers or Educators
   g. The company who manufactured the equipment

5. To whom do you think farm data belongs?
   a. The farmer
   b. The equipment dealer
   c. The company who manufactured the equipment
   d. Other ______________________________

6. What is your main reason for using/not using precision ag technologies in your operation?

7. If you use any precision ag technologies in your operation, what do you believe has been the number one benefit?

8. What do you think will be the biggest issue regarding advancements in ag production technology in the future?

9. What do you think will be the biggest issue regarding farm-level data generated from these precision ag technologies?

10. Please list any other thoughts/questions/concerns you have relating to the topic of precision ag technologies and/or data.