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Factors Influencing the Adoption of Precision Agriculture Technologies by Nebraska Producers

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Abstract: An ever-increasing world population and increasingly-volatile commodity prices have charged producers with the task of becoming more efficient. To combat this, precision agriculture technologies aimed at increasing production efficiency are continually being developed, but their adoption is not yet widespread. A survey regarding the usage of these technologies was distributed to a sample of row crop producers across the state of Nebraska and a Poisson regression was used to determine the factors influencing adoption. Results of the study indicate that larger, more tech-savvy producers and those using irrigation are more likely to adopt a higher number of precision agriculture technologies, while operator age and gross farm income were found to be non-influential factors.

Keywords: Precision agriculture, technology adoption, farm management, Poisson regression

I. Introduction

Precision agriculture technologies are believed to have numerous benefits in production agriculture, with a potentially large economic impact. They are believed to be able to improve the efficiency of farm operations by reducing overlap of inputs (seed, fertilizer, pesticides, etc.), thus saving money on input costs. Studies on specific precision agriculture technologies have shown them to consistently increase net returns (Smith et al, 2013; Shockley et al, 2012; Shockley et al, 2011). On top of the economic benefit, soil and water quality benefits can result from reduced or targeted application of inputs and irrigation water benefitting the environment through the lowered use of inputs (USDA-NRCS). According to Schieffer and Dillon (2015), producers using precision agriculture technologies have the opportunity to reduce their environmental impacts and also improve productivity and profits at the same time. In addition to reducing inputs through the improved accuracy of the technologies, it is also believed that the technologies will allow farmers to increase production due to utilizing the vast amount of information made available to them and these potential benefits could allow farmers to produce more output with less inputs (Sustainable America, 2012).

Because of precision agriculture's enormous potential economic impact, studying the factors affecting its adoption is very important. There have been many studies regarding factors affecting the adoption of precision agriculture technology specifically amongst cotton producers in the Southern United States (Lambert et al, 2015; Watcharaanantapong et al, 2014; Paxton et al, 2010; Larson et al, 2008; Roberts et al, 2004; Walton et al, 2010), regarding factors affecting adoption of precision agriculture more generally (Tey and Brindal, 2012; Daberkow and McBride, 2003), and studies of factors affecting adoption of precision agriculture technologies in other countries, such as Australia (Robertson et al, 2012), but no studies focused solely on a predominantly corn and soybean producing area. As such, this study attempts to expand upon the adoption literature by examining the factors influencing the adoption of precision agriculture technologies by producers in the state of Nebraska. In 2013, Nebraska was ranked 3rd nationally in cash receipts from all farm commodities, at $23,569,058,000, representing 5.9% of the nation's total (USDA National Agricultural Statistics Service). In 2014, Nebraska was ranked 3rd nationally in corn for grain production and 5th in soybean production (USDA National Agricultural Statistics Service). From these figures, as well as others, it's very easy to see the importance of the Nebraska row crop production industry not just on the state's economy, but also at a national level. Thus, research regarding precision agriculture technology adoption in the state is of great relevance.

The purpose of this study is to analyze the factors affecting the adoption of precision agriculture technologies amongst row crop farmers in the state of Nebraska. The variables potentially affecting adoption studied include: operator age, number of row crop acres in the operation, average yearly gross farm income, the use of irrigation, and the producer's use of a cell phone with internet access. The precision agriculture technologies studied include: GPS guidance, autosteer, variable-rate technology, automatic section control (i.e. planter row/sprayer nozzle shutoff), yield monitors, and prescription maps. This study provides a new empirical analysis of a previously researched topic. To the knowledge of the authors, this is the first study of its kind to be specific to the state of Nebraska and also one of few to be focused on predominantly corn and soybean producers, as opposed to the popularity of such studies regarding cotton producers.

Hypotheses

Coming into the study, the effects of each of the independent variables studied were hypothesized based on both a review of relevant literature and from a general sense gathered from exposure to the industry through Extension.

Age was hypothesized to have a negative relationship with the propensity to adopt precision agriculture technologies. The general notion found from the introduction of most new technologies both within agriculture and outside of it is that older generations are the last to adopt them, while the younger generations typically embrace them more quickly. Aaron Smith of Pew Research Center (2014) states that older adults face a number of hurdles to adopting new technologies, including: physical challenges to using technology, having skeptical outlooks about the benefits of the technology, and also difficulty learning to use new technologies. Additionally, several other similar studies on factors influencing the adoption of precision agriculture technologies have shown younger producers to have a higher propensity to adopt while older producers' propensity for adoption is much lower (Watcharaanantapong et al, 2014; Paxton et al, 2010; Walton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003).

The number of row crop acres in the respondents operation was hypothesized to have a positive impact on the number of technologies adopted. It would make intuitive sense for this positive relationship to exist because larger operations are, for the most part, going to have more income and thus a greater financial feasibility for investing in these new technologies. Plus, farmers with larger operations have more acres to farm and thus a greater need for efficiency, potentially causing them to turn to precision agriculture. Furthermore, the high cost of these technologies demand a higher number of acres for the cost to be spread over in order to make the investment financially feasible. After reviewing the literature, many studies have found increasing the size of operation to increase the propensity of precision agriculture adoption (Lambert et al, 2015; Walton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003). Additionally, precision agriculture technologies may be marketed more aggressively towards producers with larger operations because of the larger potential profit of the technology dealer (Daberkow & McBride, 2003).

Very similarly to number of row crop acres, gross farm income was hypothesized to have a positive relationship with number of technologies adopted. Investing in these relatively new, innovative technologies carry higher entry costs and more risk than already established technologies (Diederen et al, 2003). So, producers with higher incomes should theoretically be able to bear this risk more and be less concerned with the cost of the investment than those with lower incomes. Furthermore, many of the previously mentioned studies found income to have a positive relationship with adoption of precision agriculture technologies (Watcharaanantapong et al, 2014; Walton et al, 2010).

The use of irrigation in the producer’s row crop operation was hypothesized to have a positive impact on the number of precision agriculture technologies adopted due to the increased intensity of production. Irrigated cropland in Nebraska tends to have higher input costs and higher yields than does dryland cropland in the state. Due to their higher input costs, irrigated producers may be more interested in these technologies because of their potential for increasing efficiency and lowering costs (Smith et al, 2013; Shockley et al, 2012; Shockley et al, 2011). Additionally, the increased yields from irrigation should lead to higher gross farm incomes, further increasing propensity for adoption. Furthermore, a study on factors influencing precision agriculture technologies in cotton production showed that propensity of precision agriculture technology adoption was higher for producers who use irrigation in their operation (Lambert et al, 2015). Although this study was on cotton producers in the Southern United States, the principle of increased intensity of production is the same.

Lastly, the use of a cell phone with internet access was hypothesized to have a positive impact on the propensity of precision agriculture adoption. This variable was studied as a “tech savvy” factor; it is used as an indicator of the producer’s adoption of new technologies. The use of a smartphone implies that the producer is willing to adopt at least this one newer technology, which may lead them to adopting others. Other studies have shown a positive relationship between “tech savvy” factors, mostly the usage of a computer in the farming operation, and adoption of precision agriculture technologies (Watcharaanantapong et al, 2014; Walton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003). However, to the knowledge of the authors, this is the first study analyzing smartphone usage as a factor influencing the adoption of precision agriculture technologies.

II. Methodology

Data Collection

In order to obtain the data needed to study the aforementioned variables, 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 age, experience, county of operation, size of operation, crops produced, yields, practices, income/cost information, etc. The second section questions ask about farmers' use of specific technologies, ranging from simply having a cell phone with internet access to detailed questions about which operations they use specific technologies for. The third section covers opinions on precision agriculture technology and data ownership/privacy, as well as a question of farmers' understanding of the term "big 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, this number had to be narrowed down to 102 used in analysis to eliminate out of state responses and those with missing data. The responses used were those with the following reported: a Nebraska county of operation, age, number of row crop acres farmed (those which were 0 were also excluded), acres in production of each crop, yearly gross farm income, usage of a cell phone with internet access, GPS guidance, autosteer, variable rate technology, automatic section control, satellite/aerial imagery, chlorophyll/greenness sensors, soil sampling, yield monitor, and prescription maps. Although the sample size is quite limited, these complete responses still produce very pertinent data for this analysis.

Due to the surveys being distributed at various Nebraska Extension sponsored events across the state, the sample is not a true random sample, as producers attending Extension events may already be more progressive than the average Nebraska farmer and thus more willing to adopt new technologies. Furthermore, the randomness may also be affected by the chance that those who took the time to fill out this survey are already more interested in the topic of precision agriculture and thus may also be more inclined than the average Nebraska farmer to adopt new technologies. The funding for this project was not enough to take the measures necessary to obtain a true random sample of Nebraska row crop producers. Despite these limitations, this sample is still a very relevant sample to study the relationships between the variables studied and their influence on the adoption of precision agriculture technologies.

Developing the Variables

Due to the differences in types of independent variables used in this study, some manipulations had to be made in order for analysis. In total, there were six different factors (independent variables) potentially affecting the propensity of adoption of precision agriculture technologies.

The first factor potentially affecting adoption of precision agriculture technologies 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 adoption index that would produce an equation in which age could be used as a predictor of number of technologies adopted. 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 technology adoption index.

The third independent variable studied was average yearly gross farm income. Question 11 of the Demographic and Farming Operation Information section asked: What is your average yearly gross farm income? In order to increase response rates, the survey did not ask for specific numbers from each individual, but rather presented the question in six income ranges: <$250,000, $250,000-$749,999, $750,000-$1,499,999, $1,500,000-$2,499,999, $2,500,000-$4,999,999, and $5,000,000+. Similarly to age, in order to make the categorical income range options into empirical variables for regression purposes, the income values are assumed to be the midpoint of the range. However, the two end ranges are open ranges and thus do not have a midpoint. For purposes of this study, the assumption is made that no one with a yearly gross farm income of less than $100,000 responded to this survey. This makes the range for option (a) $100,000-$250,000, with a midpoint of $175,000. For the highest option, the range is assumed to be $5,000,000-$7,500,000, to keep consistency with the range prior to it, thus resulting in a midpoint of $6,250,000.

The next 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 precision agriculture adoption by producers, the dependent variable, an index of precision agriculture adoption was developed. The index is essentially the number of different technologies being adopted by the producer and, as such, its values range from 0 to 6, with 0 meaning the producer currently uses none of the technologies studied and 6 meaning the producer uses all of the technologies studied (GPS guidance, autosteer, variable-rate technology, automatic section control, yield monitor, prescription maps). The questions in the survey regarding usage of 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.

As can be seen from the attached survey, producers were asked about usage of more than just the six technologies that were included in the index. Question 7 and 8 from the Technology Usage were not used in analysis because so few producers have adopted these technologies. Conversely, question 9 was not used in analysis because almost every respondent reported using soil sampling in their operation, so it would not offer much benefit to be included in the index.

In setting up the technology adoption index, the use of GPS is still included despite being imbedded in the usage of autosteer, variable rate application, and prescription maps because GPS can still be used without using any of those other technologies dependent upon it. That is, all autosteer, variable rate, and prescription map users use GPS, but not all GPS users use autosteer, variable rate, or prescription maps. Thus, GPS use is still included in the adoption index as a separate technology.

The resultant dependent variable for each of the respondents was a precision agriculture technology adoption index ranging from 0 to 6.

Model

In this study, the goal was to analyze the individual effects of five different independent variables on one dependent variable; the ultimate dependent variable of interest was the count of number of precision agriculture technologies being used by each row crop producer. To accomplish this goal, a Poisson model with a log link function was used to analyze the effects of age, row crop acres, gross farm income, use of irrigation, and use of a cell phone with internet access on the number of precision agriculture technologies adopted by row crop producers in Nebraska. This approach was used in a previous, and very similar, 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. 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 precision agriculture technologies adopted by producer *i* (T_i) can be expressed as a function of five independent variables (X_i) as follows:

$$\ln(T_i) = \propto \; + \beta_i X_i \tag{1}$$

Thus,
$$T_i = \; e^{\propto \, + \, \beta_i X_i} \tag{2}$$

Using SAS to run the Poisson model produces estimated parameters (β) for each variable. In order to determine the marginal effect of each variable, we must differentiate the function (2) with respect to the independent variable, X_i, yielding:

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

As can be seen from equation 3, the sign of the estimated parameters of each variable (β_i) produced by SAS shows the sign of the marginal effect of each respective parameter.

III. Results and Discussion

As discussed above, 135 total responses were received, but after eliminating responses due to missing data, a sample of 102 was used for analysis. A summary of the demographic and farming operation variables can be seen in the tables below.

Age			**Row Crop Acres**			**Gross Farm Income**	
Range	Observations		Range	Observations		Range	Observations
≤25	4		0-499	26		≤250,000	30
25-34	26		500-999	20		250,000-749,999	31
35-44	16		1000-1499	21		750,000-1,499,999	25
45-54	16		1500-1999	14		1,500,000-2,500,000	7
55-64	22		2000-2499	9		2,500,000-5,000,000	8
65+	18		2500+	12		5,000,000+	1

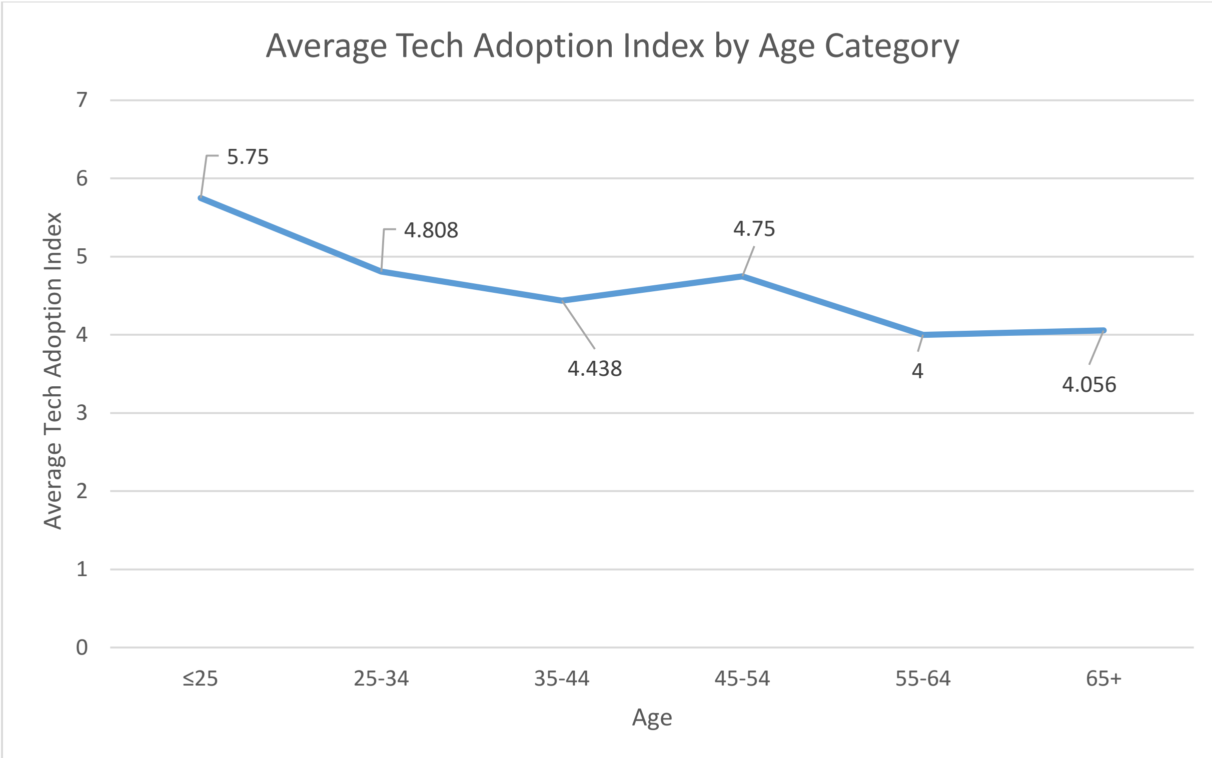
Irrigation Use			**Use of a Smartphone**	
Category	Observations		Category	Observations
Non-users	37		Non-users	21
Users	65		Users	81

Average Respondent Characteristics	
Average Age*	47.42
Average Row Crop Acres in Operation	1334.87
Average Gross Farm Income*	$971,813.73
Percentage Using Irrigation	63.73%
Percentage Using Cell Phone with Internet Access	79.41%
Average Number of Technologies Adopted	4.47

*Calculated using the midpoints discussed in section I above.

As seen above, the average age of respondents was 47.42 years, slightly lower than the reported average age of 55.7 years for principal operators in Nebraska in 2012 (USDA NASS). However, as shown in the above table, the sample was quite evenly distributed amongst the age range, excluding ≤25, which is consistent with the population of interest, as producers in this age range represent only approximately 1% of principal operators in the state (USDA NASS). The average number of row crop acres in a respondent's operation was 1,334.87—higher than the average size of a Nebraska farm in 2012 of 907 acres, most likely due to the fact that the USDA numbers include a large amount of small operations, such as hobby farmers (USDA NASS). The average gross farm income of respondents was $971,813.73, most likely a good representative number for an average row crop operation with a principal operator whose main source of income is farming. The percentage of respondents using irrigation was 63.73%. In 2014, approximately 59% of all corn and soybean acres planted in Nebraska were irrigated, so this number is quite representative of the mix in the state. The percentage of respondents who reported owning a cell phone with internet access was 79.41% and, of the six different technologies studied, the average number of precision agriculture technologies being used by a respondent was 4.47. These numbers may be slightly higher than the average Nebraska row crop farmer, as the sample may be using more precision agriculture technologies due to the reasons discussed in section II above.

Prior to running the Poisson regression, each variable's relationship with the technology adoption index was analyzed separately in order to examine their individual effects. In putting together these charts, the average technology adoption index of each category of each variable was found and then plotted. The first variable examined was age; the results can be seen below.

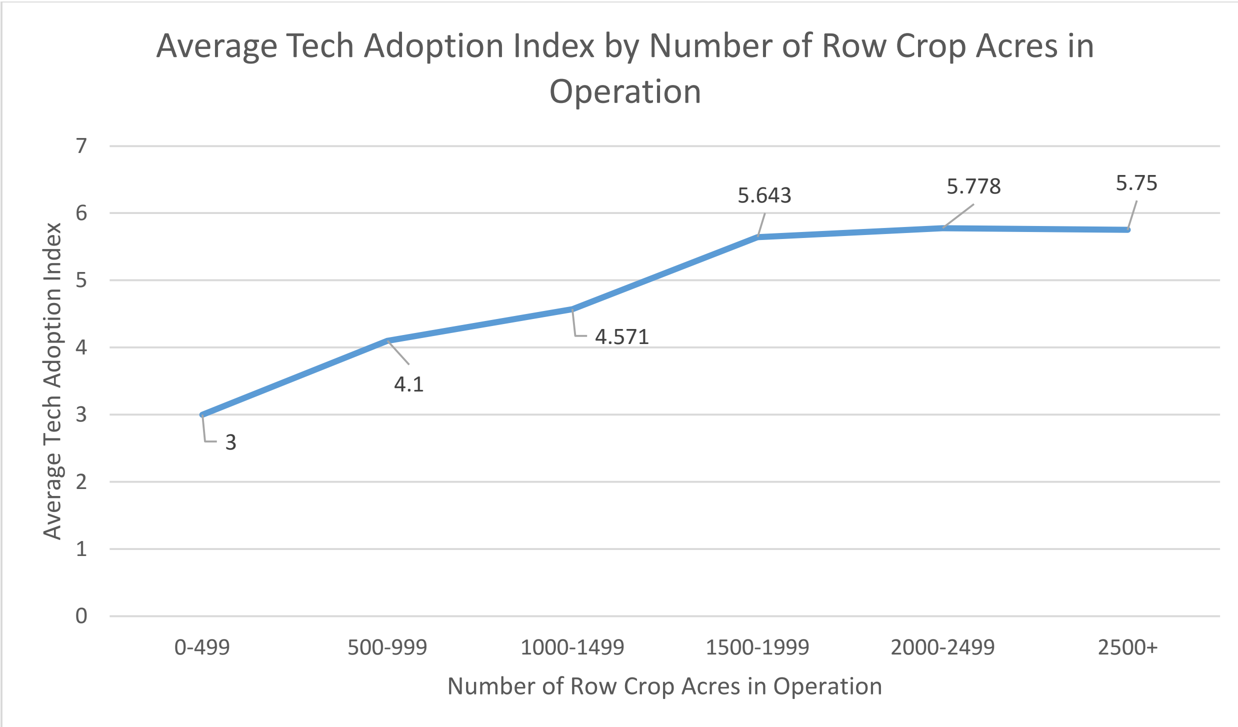


One-Way Analysis of Variance—Dependent Variable: Operator Age

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	16.5819384	3.3163877	0.93	0.4660
Error	96	342.8298263	3.5711440		
Corrected Total	101	359.4117647			

As can be seen in the chart, there is an observable downtrend in the average number of technologies adopted as age increases, which is consistent with the hypothesis that older producers are adopting less technologies than those who are younger. A one-way analysis of variance (ANOVA) was performed on the data in order to determine whether or not the mean number of technologies adopted for each age range was significantly different. The results of this ANOVA can be seen in the above table; the f_{obs} of 0.93 and corresponding p-value of 0.4660 indicates that there is not a statistically significant difference amongst the average mean technology adoption index of the six age ranges. Although the ANOVA did not show a statistically significant difference in adoption index amongst the different age ranges, age was still included in the regression due to its observable negative relationship with adoption.

The next variable examined was the number of row crop acres in the respondent's operation. The results can be seen below.

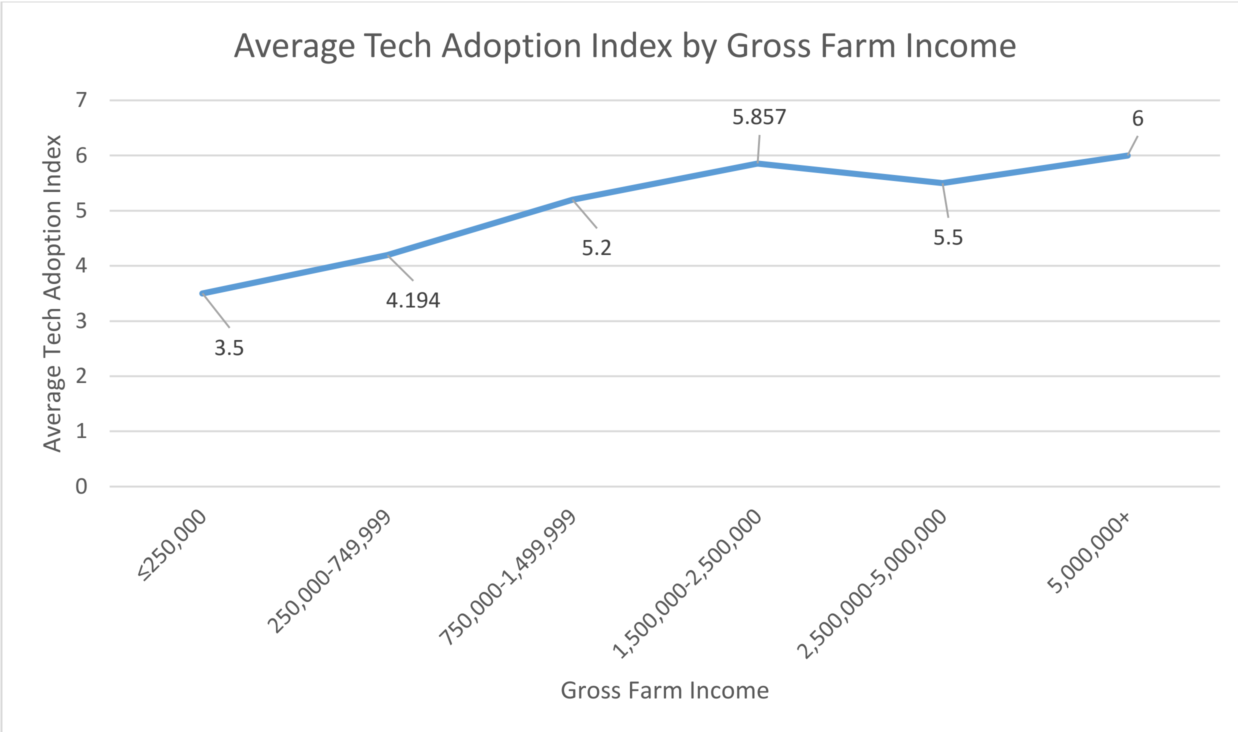


One-Way Analysis of Variance—Dependent Variable: Row Crop Acres

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	113.4490663	22.6898133	8.86	0.0000
Error	96	245.9626984	2.5621114		
Corrected Total	101	359.4117647			

The chart shows an obvious positive relationship between the number of row crop acres in the operation and the average number of precision agriculture technologies adopted, consistent with the hypothesis for the relationship between number of row crop acres and number of technologies adopted discussed in the introduction. Again a one-way ANOVA was performed on the data, and its results can be seen in the above table. The f_{obs} of 8.86 and resulting p-value of <0.0001 allow us to reject the null hypothesis that the mean number of technologies adopted by each size category are the same and conclude that at least one is significantly different from the rest and there must exist some sort of relationship between number of row crop acres in the operation and the number of precision agriculture technologies adopted.

The next variable examined was gross farm income. The results are shown below.

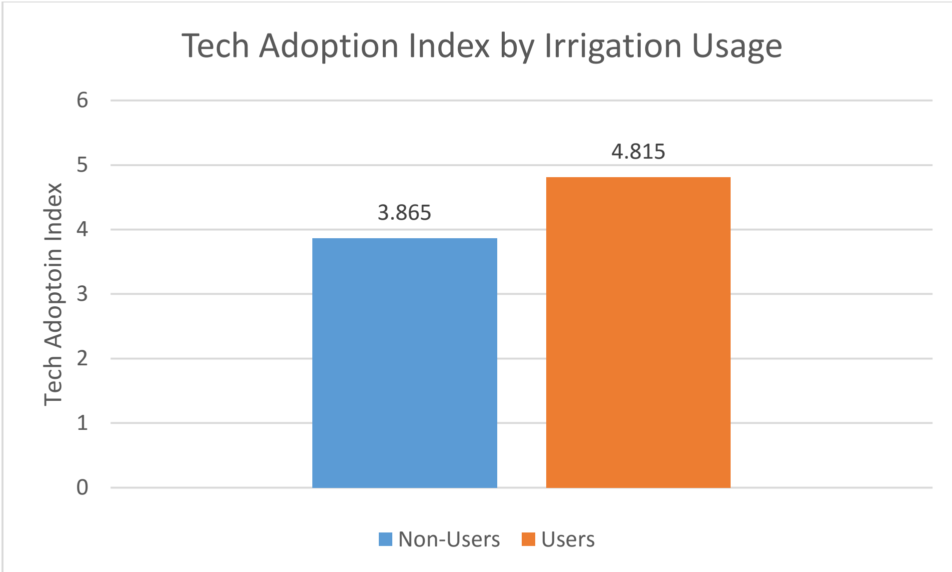


One-Way Analysis of Variance—Dependent Variable: Gross Farm Income

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	68.2159122	13.6431824	4.50	0.0010
Error	96	291.1958525	3.0332901		
Corrected Total	101	359.4117647			

Much like row crop acres, the chart shows a very similar obvious positive relationship between gross farm income and number of technologies adopted, consistent with the hypothesis for this variable. A one-way ANOVA was performed on the data and its results can be seen in the above table. The f_{obs} of 4.50 and p-value of 0.0010 allow the null hypothesis that the mean adoption index is equal for all income ranges to be rejected, signifying the existence of a relationship between gross farm income and the number of technologies adopted by producers.

The fourth variable examined was the usage of irrigation in the row crop operation. The results of the analysis can be seen below.

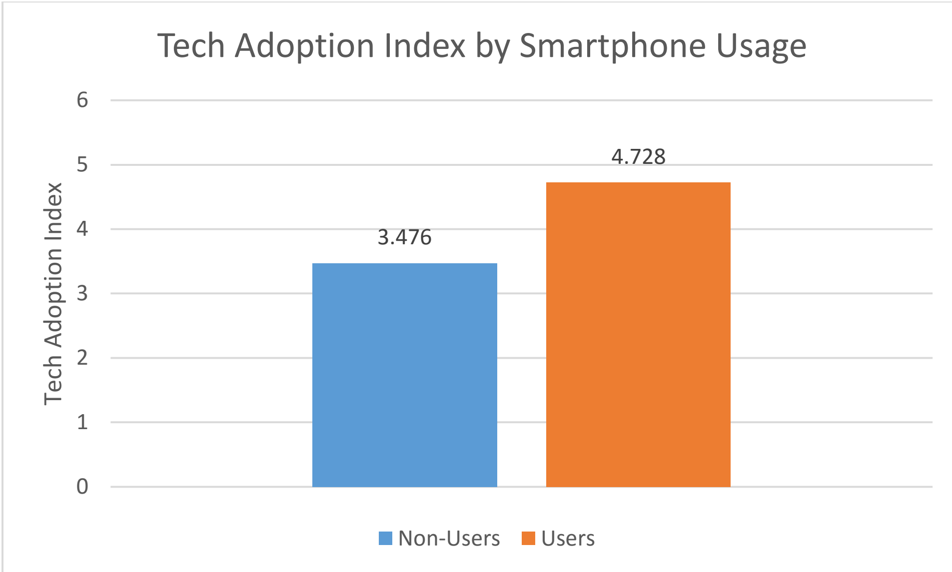


One-Way Analysis of Variance—Dependent Variable: Irrigation Usage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	21.3028250	21.3028250	6.30	0.0137
Error	100	338.1089397	3.3810894		
Corrected Total	101	359.4117647			

As can be seen in the chart above, the average number of technologies being used by irrigators is 4.815, higher than that of non-users, 3.865. This difference essentially tells us that, on average, those using irrigation in their row crop production are adopting one more precision agriculture technology than those not using irrigation in their operation. A one-way ANOVA was performed on the data, and the resulting f_{obs} of 6.30 and p-value of 0.0137 prove that there is a statistically significant difference between the average number of technologies being adopted by irrigators and non-irrigators in Nebraska, with those using irrigation adopting more. This is also consistent with the hypothesis that those using irrigation will be more inclined to adopt precision agriculture technologies due to the increased intensity of production that comes with irrigation use.

The last variable examined was the usage of a cell phone with internet access. The results are shown below.



One-Way Analysis of Variance—Dependent Variable: Smartphone Usage

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	26.1489781	26.1489781	7.85	0.0061
Error	100	333.2627866	3.3326279		
Corrected Total	101	359.4117647			

Producers who do own a cell phone with internet access used an average of 4.728 precision agriculture technologies, while producers who do not had a lower average index value of 3.476, again consistent with the hypothesis discussed in the introduction for this variable. To test for equality of the mean adoption index for users and non-users, a one-way ANOVA was performed, which resulted in an f_{obs} of 7.85 and p-value of 0.0061. Thus, the conclusion can be made that the average technology adoption index of producers who own a cell phone with internet access and those who do not are significantly different, with producers owning a cell phone with internet access adopting more precision agriculture technologies in their operation than those who do not.

After each of these individual analyses, a Poisson regression was run in SAS. The results of the regression are shown in the table below.

Variable	Poisson Model Parameter Estimate[1]	Standard Error	P-Value
Intercept	1.5323***	0.1736	0.0000***
Operator Age	-0.0015	0.0032	0.6346
Row Crop Acres	0.0001*	0.0000	0.0531*
Gross Farm Income	0.0000	0.0000	0.9213
Non-Irrigator	-0.1585[2]	0.1045	0.1294[2]
Smartphone Non-User	-0.2387*	0.1323	0.0711*

[1]Significance at the 10%, 5%, and 1% level are indicated by one, two, and three asterisks, respectively.
[2]The p-value for irrigation was 0.1294—very close to statistical significance at the α=10% level.

As can be seen in the above table, operator age has a negative parameter estimate, meaning that increasing operator age results in a lower number of technologies being adopted, which is consistent with the hypothesis and relevant literature (Watcharaanantapong et al, 2014; Walton et al, 2010; Paxton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003), but this relationship is not statistically significant.

Acres has a positive parameter estimate and its relationship with the technology adoption index is also statistically significant, meaning that producers with larger operations are more likely to adopt a higher number of precision agriculture technologies than those with a lesser number of row crop acres in their operation. This result is consistent with the literature (Lambert et al, 2015; Walton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003) and also consistent with the hypothesized result above.

Gross farm income is estimated to not have an effect on technology adoption index, as indicated by the essentially zero parameter estimate and marginal effect; a result inconsistent with the hypothesis and other similar studies. However, this is most likely due to income being too closely correlated with row crop acres.

In terms of irrigation practices, producers not using irrigation in their operation have a negative parameter estimate, meaning that producers that irrigate are more likely to adopt a higher number of technologies compared to those not using irrigation. Although not quite statistically significant at the α=10% level, the p-value of 0.1294 indicates the use of irrigation still obviously has some impact on the number of precision agriculture technologies amongst row crop farmers in Nebraska. This result would be consistent with the hypothesis, as other studies, such as Lambert et al (2015) have shown the use of irrigation to increase the propensity of adoption of precision agriculture technologies.

As seen in the table, the variable with the largest parameter estimate is the usage of a cell phone with internet access, which is also statistically significant. This result is consistent with the hypothesis and with other studies examining the usage of other technologies, such as computers (Watcharaanantapong et al, 2014; Walton et al, 2010; Larson et al, 2008; Daberkow & McBride, 2003).

IV. Conclusions

This study examined factors influencing the number of precision agriculture technologies adopted by row crop producers in Nebraska. A Poisson model was used to analyze data collected from a 2014-15 survey distributed at various Nebraska Extension events across the state. This study contributes to precision agriculture adoption literature in two main ways: firstly, to the knowledge of the authors, it is the first study of its kind solely focused on a predominantly corn and soybean producing region and also the first to examine the usage of a smartphone as a factor influencing adoption.

Two of the five variables studied were found to have a statistically significant effect on the number of technologies adopted: number of row crop acres in the operation and the usage of a cell phone with internet access. Number of row crop acres in the operation had a positive effect on the number of technologies adopted, meaning larger producers are more likely to adopt a higher number of precision agriculture technologies. This result was expected, as larger farmers are more likely to be able to afford the investment in the technology and also have an increased need for efficiency in covering larger areas. Producers not using a cell phone with internet access was found to have a negative effect on the number of precision agriculture technologies. This result also makes sense, as the usage of a smartphone is potentially an indicator of technological competency, which may lead to the adoption of further technologies. It should also be noted that irrigation usage was very close to statistical significance. The results indicated that not using irrigation in the operation had a relatively large negative effect on the number of technologies adopted, meaning that irrigated producers are more likely to adopt more technologies than those solely using dryland practices. This result is most likely due to the increased intensity of production that comes along with the use of irrigation and the resultant increases in production cost and importance of accurate placement of inputs. Lastly, it is of interest to note that although operator age had a negative parameter estimate, the relationship was nowhere close to statistical significance, meaning that age does not have an effect on number of technologies adopted. This result is inconsistent with general expectation and several similar studies, and this may be due to the fact that older producers most likely have built up larger operations and are in a much better position financially to make the investment in said technologies. Thus, further study of adoption using an age/acre term that would account for this potential correlation could be of great value.

These results may be of interest to manufacturers and retailers of precision agriculture technologies in terms of their marketing strategies. Additionally, these results may be of interest in determining groups for targeting educational efforts on usage of precision agriculture.

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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,

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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.