2018

Adoption of Conservation Practices and Precision Technologies in South Dakota: An Empirical Analysis

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ADOPTION OF CONSERVATION PRACTICES AND PRECISION TECHNOLOGIES IN SOUTH DAKOTA: AN EMPIRICAL ANALYSIS

BY

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Economics

South Dakota State University

2018

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This thesis is approved as a creditable and independent investigation by Allen P. Deutz, candidate for the Master of Science in Economics degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidates are necessarily the conclusions of the major department.

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ACKNOWLEDGMENTS

I wish to thank everyone in the Economics Department at South Dakota State University that made my transition from a dairy farmer to graduate possible, and fairly smooth. I would particularly like to thank Dr. Joseph Santos and Dr. David Davis for their help and encouragement in my first year of Graduate School, without which I would have not made it through the first semester. Thank you both for the extra time you spent helping me with course work. It was greatly appreciated.

I wish a special thank you to my thesis advisor, Dr. Deepthi Kolady, to whom I was also a Graduate Research Assistant for the last two years. Her help and encouragement provided me with the structure to make it possible to complete this thesis, as well as providing me with her experience conducting research. Thank you for motivating me to pursue all the opportunities you provided me over the course of the last two years.

I would also like to thank my committee members, Dr. Matthew Diersen and Dr. Larry Janssen, for their time with this thesis. I would also like to thank my fellow graduate students for their help during my studies during the first year. Someone was always there when I had a question, and I will not forget that.

I would also like to thank my family, particularly my father Paul, for his help keeping the farm running while I pursued this degree. I would not have been able to do both without your help over the last two years. Thank you. I also want to thank my children, Samuel, Autumn, Elsie, and William. You are the motivation for everything I do.

And finally, I wish to thank my lovely wife, Kathleen, for putting up with my antics over the last two years. Her love, support, and strength has kept me in check and she is the glue that holds our family together. I love you and thank you for everything you do for me and our family.

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ABSTRACT

ADOPTION OF CONSERVATION PRACTICES AND PRECISION TECHNOLOGIES IN SOUTH DAKOTA: AN EMPIRICAL ANALYSIS

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Advances in conservation agriculture and precision agriculture technology practices have contributed to the adoption of conservation practices that reduce externalities from agricultural production, but this conversion was usually coupled with economic incentive, whether from increases in fertility and yield, or payments for on-farm retirement or restoration practices. This study expands on this theme, evaluating the connection between conservation and the increased use of various precision agriculture technologies. The study uses survey data collected from South Dakota farmers and ranchers, with responses from 28 counties and over 500,000 acres of crop, pasture, and range land to address the following three objectives: 1) estimate the adoption rates of conservation agriculture and precision agricultural technology practices in South Dakota; 2) identify the factors influencing farmer's adoption decisions; 3) examine the relationship between farmers' adoption decisions on conservation agriculture and precision agricultural technology practices, and 4) conduct a qualitative analysis of farmers' preferences and non-preferences for conservation agriculture and precision agriculture technology. Economic analysis using multinomial logit and bivariate probit models are employed to help identify the factors influencing adoption decisions and to examine the relationships between various conservation and precision bundles as well as an overall connection between the two practices. Results from the study show a significant positive relationship between adoption of conservation agriculture and cattle operations and a significant negative relationship between conservation agriculture and highly productive land. The study also reveals off-farm income negatively effects the more labor-intensive and capital-intensive practices such as diverse crop rotation and precision agriculture technologies. Findings from the study imply that targeting farmers with certain characteristics should be a goal of any policy wanting to increase adoption of any of these practices.

Chapter I: Introduction

Although conservation in agricultural regions has been an increasing goal of state and federal government entities in the United States since the dust bowl era of the 1930's, intensification of agricultural production systems has caused many adverse environmental consequences such as soil degradation, soil erosion, and water pollution. Adoption of conservation agriculture practices (e.g. no-till, diverse crop rotations, and cover crops) is considered as a socio-economically viable approach to manage the agricultural system for improved and sustained productivity, soil health, and increased profits (CTIC, 2017). Over the last few decades, technology has greatly changed the way farmers view agriculture. Biotechnologies have changed the way we farm, giving farmers the opportunity to do more with less. Genetically modified organisms, like glyphosate (Roundup) tolerant seeds, have reduced practices like cultivating crops and other forms of tillage, allowing farmers to increase their use of conservation agriculture practices like no-till farming, which reduces fuels usage and minimizes soil disturbance (Roberts et al, 2006). This new technology allowed farmers to conserve as well as improve best management practices, which in turn helped increase output.

Conservation Agriculture (CA) "is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity" (Cornell, 2018). Benefits from inputs reduction can be measured against a standard practice profitability, however externalities are harder to measure using this method. Farmers and land owners tend to weigh these externalities against individual monetary and personal benefits, where less benefit in either category lessens the chance of conservation adoption. While the value of CA benefits is realized among farmers, the adoption rates of such practices tend to fall on a sliding scale of adoption, where practices that are profitable within a cropping cycle are adopted at a higher rate than practices that are beneficial over a longer time period (Canales et al, 2014). Adoption of CA practices that have longer term benefits, but less short-term gain tend to need subsidies to entice adoption of these practices to compensate for additional time and added costs of implementation (Lichtenberg, 2001, Gedikoglu et al, 2007, Canales et al, 2014).

Because conservation practices provide synergistic environmental and economic benefits both on and beyond farms, federal and state governments provide financial incentives for farmers to adopt these practices. Examples include federal programs such as Conservation Stewardship Program (CSP) and Environmental Quality Incentive Program (EQIP). In a recent state level effort to address water quality issues, the Iowa Department of Agriculture started a pilot program in November 2017 where farmers will be given a $5/acre crop insurance premium discount to plant cover crops (Iowa Farm Bureau, 2017). Despite all these efforts, adoption of conservation practices on farms remains low in the US (CTIC, 2017).

Farmers have also improved technology from a data collection and utilization perspective. Today's farmers use this new data driven technology to precisely apply seed, fertilizer, and herbicides to their fields that places the right input, in the right amount, in the right place, at the right time, improving the utilization of inputs to maximize the potential of the crop they are growing. They are conserving inputs through efficiencies, while trying to maximize output. Precision Agriculture Technology (PAT) is a ubiquitous term that covers many different aspects of agriculture, ranging from livestock production to grain and seed oils production to fruits and produce production. A definition given by the Natural Resources Conservation Service (NRCS) states, "a management system that is information and technology based, is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield, for optimum profitability, sustainability, and protection of the environment (USDA, 2007). The financial returns of PAT practices tend to be more concrete and immediate, where the returns from CA practices tend to be more abstract or realized over the longer term. With the benefits being realized over different spectrums, this effects reasons for adoption. With PAT and CA taking different approaches to adoption, studies on joint adoption of these practices and the relationship and motives behind the adoption decision have been lacking. Additionally, while some work in South Dakota has been done on no-till and crop rotation adoption decisions (Janssen and Harer, 2010), no one has looked at the drivers of adoption of these practices in South Dakota and the relationship between adoption decisions, leaving a gap in literature.

Technology advances over the years have contributed to more conservation practices that reduce negative externalities from agricultural production, but this conversion was usually coupled with economic incentives, whether from increases in soil fertility and yield, or payments for on-farm retirement (Conservation Reserve Program among others) or other restoration practices. This study expands on this theme, evaluating the connection between conservation and the increased use of various precision agriculture technologies.

Research Objectives

The specific objectives of the research are to:

1) estimate the adoption rates of conservation agriculture and precision agricultural technology practices in South Dakota;

2) identify the factors influencing farmers' adoption decisions;

3) examine the relationship between farmers' adoption decisions on conservation agriculture and precision agricultural technology practices; and

4) conduct a qualitative analysis of farmers' preferences for CA and PAT.

Findings from this project will be of value for farmers, policy makers, and machine manufacturers in the following ways: (i) improved the understanding of drivers and challenges of adoption of conservation practices and precision agriculture technologies, (ii) better insights for policy makers to frame policies that incentivize the adoption of these practices and technologies, and (iii) improved machine manufacturers' understanding of constraints faced by farmers in their adoption decisions.

The following research will be presented as follows. Chapter II starts by reviewing literature on both PAT and CA practices, providing information on each practice individually. Chapter III will provide information on survey data collection and methods, which does lead into descriptive statistics about farmers, overall and by practice adoptions choices, that is compiled and compared. Following this, a conceptual and empirical model is provided. Chapter IV contains results from a multinomial logit analysis and a bivariate probit regression analysis. Chapter V provides a tabular analysis of the Likert scales data on farmer adoption and non-adoption decisions. Chapter VI concludes with final thoughts and policy implications.

Chapter II: Literature Review

This chapter will be split into two parts, precision agriculture technology and conservation agriculture practices. Because of the lack of research about joint adoption, evaluating adoption of each practice individually provides a basis of the factors and barriers influencing adoption.

Precision Agriculture Technology

This study focuses on its application regarding row crop production in South Dakota, which is primarily corn, wheat, and soybeans. The primary PATs focused on by our survey were autosteer, variable rate technologies (VRT), Global Positioning System (GPS) guidance systems, yield monitors (YM), with data also collected on automatic section control, grid soil sampling and prescription field maps, aerial/satellite imagery, and crop tissue sampling.

PAT adoption has been the focus of many studies over the last few decades. Daberkow and McBride (1998) focused on characteristics of early precision agricultural adopters. Through a survey of 950 corn farmers in 16 states, they accessed whether farmers adopted any of the following PAT's: YM, VRT, and grid soil sampling. They concluded that adopters were more likely to be younger, have some post-secondary education, and have farming as their full-time occupation as well as operating more acres, being more highly leveraged, renting a higher proportion of their acres, and more specialized within their operation. They also tended to be from high corn producing states (Daberkow and McBride, 1998). Nearly twenty years later, Schimmelpfenning (2016) found some of those characteristics to be consistent with his research, particularly the type of farm, corn and soybeans. Farm size also had a positive correlation with PAT adoption. The positive correlation with larger farm size and PAT adoption was theorized early by Debertin (1998), estimating that early, larger adopters will have a competitive advantage over early, smaller non-adopters during periods of lower output prices (Debertin, 1998). Assuming PAT adoption also improves overall returns and makes adopters lower cost farmers, larger farmers will have a competitive advantage which may lead to increased consolidation.

A comprehensive overview of the state of PAT adoption in the US, focused on yield monitors and GPS maps, guidance systems, and variable-rate application technologies (Schimmelpfennig and Ebel, 2011). Their work showed a steady increase of all technologies over time, again showing a higher adoption rate in predominately corn, soybean, and wheat producing areas. They found that adopters of PAT's had higher yields, particularly those adopting YM. It was also found that fuel expenses were lower. It was also noted that YM adoption was faster for farmers who used conservation tillage practices. They noted this happened about the same time as herbicide resistant crops started becoming popular, which could have been the driver in reduce tillage as well. In 2006, Roberts et al supported this finding while researching the connection between no-till and conservation tillage practice and herbicide-resistant cotton (Roberts et al., 2006). They found that the greater adoption of herbicide resistant cotton led to an increase in the adoption of conservation tillage.

Another result from Schimmelpfennig and Ebel (2011) was that as technology has been advancing, adoption has been increasing, but at a slower rate than anticipated. Their research was significant in that although previous research had shown correlations with higher yields and overall input costs, farmers were still hesitant to adopt new PA technologies. Schimmelpfennig (2016) again focused on the previously mentioned technologies. Like Schimmelpfennig and Ebel (2011), yield monitors had the highest adoption rates, followed by GPS guidance systems, then variable-rate application. An evaluation was also done on profitability, using net returns and operating profits, which ranked the profitability in a similar order as the adoption rates (GPS mapping, which includes the use of a yield monitor, ranked first), implying a correlation between profitability and adoption rates (Schimmelpfennig 2016). The positive correlation between PAT adoption and profitability appears to be a barrier to adoption, which leads to the technology needing to be more profitable or less expensive to increase adoption rates in the future.

This theory on the relationship between adoption of a technology and profitability is supported by Tozer (2009) who reported that even if technology adoption is profitable, the rate of return might not be high enough to entice farmers to adopt the technology. Tozer (2009) approached the investment in PAT from a capital budgeting perspective. Using a Net Present Value (NPV) approach, Tozer (2009) found that under different scenarios of similar farms, the adoption decision changed. If a famer was choosing between PAT and conventional systems, PAT had the higher returns. However, several scenarios resulted in neither system reaching the hurdle rate, effectively say neither was profitable enough to adopt. In a scenario of adopting new technologies, such as PAT, the decision would be no.

Using Kansas Farm Business Management Association data, Miller et al (2017) evaluated adoption characteristics of farmers using a multinomial logistic regression framework. They evaluated three technologies: yield monitors, variable rate fertilizer application, and precision soil samples, to create eight bundles of PATs ranging from adopting none of the PATs to adopting them all. The results indicated that increasing the age of the farmer increases the likelihood of adopting none of the practices and decreased the likelihood of adopting them all. Another interesting result indicated that farms that increased in size were actually less likely to adopt any PATs. They theorize that farms can expand production in two ways, increasing efficiency of inputs (PAT) or increasing acres. With constraints on capital, a farmer can choose between spending that capital on expanding acres or increasing output on current acres. If the farmer chooses to expand through acres, it limits capital and reduces other expenditures. Of the aspects that had no significant effect, the quality of land was one that stood out.

Another aspect of adoption is the ability to bundle technologies. Bundling technologies that can be used in tandem may improve the usefulness of adding additional technologies. Schimmelpfennig and Ebel (2016) found that bundling some PATs together resulted in lower average variable production costs but adding some additional ones did not lower average variable production cost (Schimmelpfennig and Ebel, 2016). Similarly, Lambert et al (2015) focused on adoption of bundled technologies by cotton growers and found higher adoption rates among larger operators on higher yield potential ground closer to export markets (Lambert et al, 2015).

Conservation Agriculture

The Food and Agriculture Organization of the United Nations (FAO) defines the goal of CA as "aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations" (FAO, 2018). Montgomery (2017) also used a similar definition in his book "Growing a Revolution: Bringing Our Soils Back to Life". Montgomery (2017) lays out an argument for widespread adoption of these three primary principles, which he also refers to as regenerative agriculture. With this broadly accepted definition of CA gaining consensus among researchers and proponents, the three conservation practices chosen to focus on are cover crops, no-till and/or strip-till, and crop rotation. Once the definition of CA is established, the factors of adoption rates of these practices can be evaluated.

A Kansas survey of a farmer's likelihood of adopting different conservation practices at different monetary values showed that there was a strong positive correlation between the amount of compensation received for a practice and the amount of capital and labor required for the practice (Canales et al., 2014). Canales et al. (2014) administered a survey to farmers attending workshops around Kansas in the winter of 2013-2014, asking questions about the farmer's willingness to participate in several conservation practices. The practices were bundled into four groups: 1) no-till, 2) no-till and cover crops, 3) no-till, cover crops, and conservation crop rotation, and 4) the previous three plus VRT. As practices were added, the likelihood of adoption was lower at each rate of compensation. No-till on its own required the least amount of incentive for adoption. A Maryland survey revealed a similar result when questioning farmers about which methods were adopted to reduce soil erosion, showing a negative correlation between frequency of practice use and cost. However, when measured against more erodible topography, farmers were more apt to adopt more costly practices to mitigate the problems (Lichtenberg, 2001). Another survey-based study from Vermont also found similar results with farmers likelihood to participate in the Natural Resources Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP) positively correlated with the financial incentives of the program (Miller, 2014).

For cover crops, financial incentive is also linked to increased adoption. Ramírez et al (2015) focused on the adoption of cover crops in Iowa after the Iowa Natural Resource Service (NRS) provided cost-share through a Water Quality Initiative (WQI). They found that cost share did increase adoption rates in both acres planted and acres total. They determined this by setting a baseline with farmers who had adopted a cover crop prior to 2010 (adopters) and comparing it to current levels of adoption. They determined that cost share had increased adoption from 14% to 15%, while increasing the acres in cover crops from 116 to 123.

This concept appears very intuitive, increasing incentives increases participation. However, if the economic incentive can be perpetually created by the practice itself, there is a lesser need for subsidy incentive payments. For example, in areas with highly erodible soil, no-till practices may need little to no additional incentives for farmers to adopt the practice because of increased fertility of the practice. The conservation goal is achieved by increased profitability of the farmer. But, if the goal of that highly erodible land is for it to be fallow and stabilized by native grasses, a higher incentive payment is needed to offset the opportunity costs of leaving the land fallow, such as the Conservation Reserve Program (CRP) or another similar practice.

Off-farm income can also influence the adoption decisions of farmers. Research involving farmers from Iowa and Missouri found that off farm income had a positive effect on capital intensive conservation practices, but a negative effect on labor intensive practices. In the study, farmers with modest off farm income ($10,000-24,999) were more likely to inject manure and have grass waterways than farmers with higher off farm incomes ($25,000-49,999). The same study also found a correlation with size and labor-intensive conservation activities, drawing the conclusion that as farm size increases higher managerial requirements are needed that limit the farmer's ability to have any off-farm income (Gedikoglu, 2007). Similar results were also observed in Maryland on willingness to implement a conservation practice (Lichtenberg, 2001).

In a focused literature review of conservation adoption, Lesch and Wachenheim (2014) identify farmer characteristics that provided both inconsistent and consistent contributions to conservation adoption. Some notable characteristics that were inconsistent were age, education, farm size, income, and off-farm income. A major difference in their literature review was their focus on a different subset of conservation practices, particularly Conservation Reserve Enhancement Program (CREP), riparian buffers, and Environmental Quality Incentive Program (EQIP). However, tillage practices were evaluated with them focusing on conventional, reduced, and conservational tillage. They found that age was negatively related with the adoption of conservation tillage, but no clear link was found with education levels and off farm employment. It was also found that the quality of the land had a negative relationship with the adoption of conservation tillage, possible from the quality of the land reducing the benefits of no-till in the short-term. Regarding no-till, a negative relationship with number of acres farmed and farming experience was observed. The barrier of higher equipment costs could be linked to both of these factors, with costs being higher per acre for these farmers as well as a shorter duration for a positive economic payback.

Another Kansas study looked at the characteristics of farms and their operators and their marginal effects on the adoption of no-till, cover crops, and the use of manure. Again, the findings were inconsistent with other similar studies and some predetermined assumptions. Some of the unexpected results were cattle having a negative effect on using cover crops, off-farm income reduced the use of no-till and being involved in NRCS programs, EQIP and CSP negatively affected the marginal adoption of no-till (Gong and Bergtold, 2013). The assumption for a positive relationship between livestock and cover crops was due to winter wheat grazing practices in Kansas. No-till and off-farm income could be thought to have a positive relationship due to time constraints of the operator. However, equipment costs may create a barrier for farmers with off-farm income due to them inherently having off farm income because they lack adequate resources being generated on the farm already. As for involvement in government programs, it was thought practices such as no-till would increase the likelihood of adoption, however it reduced it. Cover crops adoption did have a positive relationship, which lead the authors to believe the program's objective may be steering priorities in federal funding.

Chapter III: Methods

The data used for this study comes from a farm level survey conducted in South Dakota during the Spring of 2017. The survey collected extensive data about the farm's location, size, land use, crop data, livestock (cattle) enterprises, and conservation and precision agricultural practices. Data were also collected on farmer perceptions of CA and PAT practices as well as risk perceptions using a Likert style ranking system. Additionally, farmer characteristics such as age, education, and off farm employment were also collected, as well as risk tolerance and various other information about their operation. See Appendix 1.

Farmers were chosen from a list of the top ten corn, soybean, and wheat producing counties in 2015 in South Dakota. For corn and soybeans, the top ten counties were the same. They included Beadle, Bon Homme, Brookings, Brown, Charles Mix, Hutchinson, Kingsbury, Minnehaha, Spink, and Turner. The top ten wheat producing counties included four overlapping counties, Brown, Charles Mix, Hutchinson, and Spink, with the addition of Clark, Codington, Day, Pennington, and Potter. To have a balanced cross section of farmers, 800 were designated towards the top corn and soybean producing counties and 400 towards the top producing wheat only counties. Using this method allowed for some overlapping responses from wheat farmers in the top corn and soybean producing counties, while increasing the response rate of wheat farmers overall in wheat counties to have a more balanced response. Farmers were then selected by random, with a target weight of approximately 21% of farmers chosen from each corn and soybean county, and approximately 30% of farmers from each wheat county. 1200 surveys were sent out January 27, 2017 to 14 primary counties, with responses from farmers that identified as primarily farming in 28 counties (Table 3-1). Of the 1200 surveys, 37 were returned to sender, 59 were returned by recipient with no or insufficient

Table 3-1. South Dakota Counties Represented in the Survey ***(Primary Counties)***

Beadle	17	*Coddington*	4	Hand	3	Moody	7
Bennett	1	Corson	1	*Hutchinson*	9	Pennington	1
Bon Homme	12	Day	5	*Kingsbury*	13	Perkins	1
Brookings	17	Douglas	2	Lake	2	*Potter*	8
Brown	15	Edmunds	2	Lincoln	2	*Spink*	21
Charles Mix	10	Faulk	1	Meade	1	*Turner*	16
Clark	3	Hamlin	1	*Minnehaha*	22	Yankton	1

Source: Author's Survey

data, and 198 contained usable data.

Figure 3-1 shows the geographic positions of the responding operations. There are 21 counties highlighted, five more than surveys were sent. This discrepancy can be accounted for

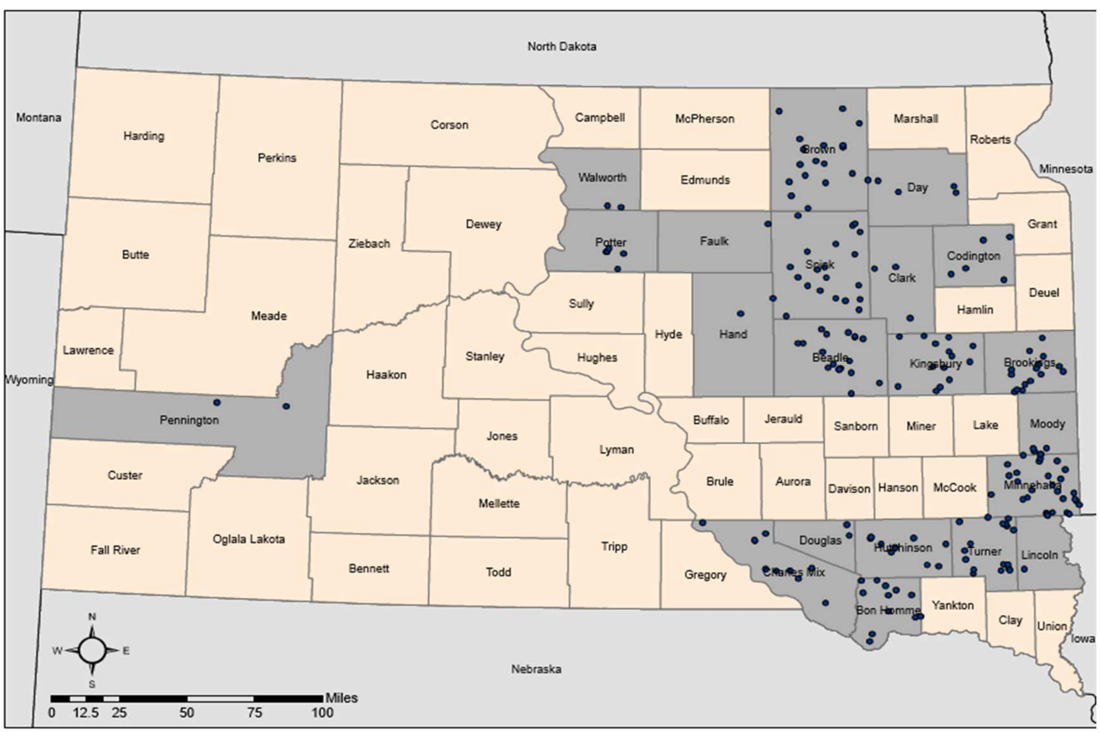

Figure 3-1: Map of South Dakota Counties with Locations of Survey Respondents

Source: Author's survey

because of respondents farming in one county and living in another county. It was asked what the county was the farmers primarily farmed, so more counties were listed. Two farmers claimed Potter county, however there were seven located in Walworth county, a county that no one claimed as the primary county they farmed.

Descriptive Data

Farmer characteristics

The average age of the overall farmer respondents was 59.45 years, with 94% responding as the primary operator. This figure is higher than the average age of 55.9 years of primary operators from the 2012 Agriculture Census (USDA, 2012). The average farm size was 2,667.1 acres overall, with 1905.4 acres in crop production and a median of 1,094 acres. With this lower mode than mean for cropland acres, skewness (2.78) and kurtosis (11.68) levels were high and the upper 10% reporting 4,600 acres or higher. This should be noted in interpreting these characteristics. Some additional means were 600.5 acres in pasture, 108.8 in hay acres, and 52.3 acres in some federal reserve program. There was a discrepancy between the total of owned and rented acres (2,675.8) and the total of overall acres in some sort of income generating enterprise which comprised the average farm size (2,667.1) of 8.7 acres. Although not verified in the survey, this discrepancy could be because of farmers including their farm sites as acres owned, but not included in acres in production. This number of acres is larger than NASS data, which estimates 2016 average farm size at 1,397 acres. Farmers with any form of off-farm employment were at 22.5%, lower than the 2012 Agriculture Census figure of 56.1 %. Brown et al (2015) found that the rate of farmers with off-farm employment had been increasing, up to 41.7% in 2012. It's possible this discrepancy of our farmer respondents being larger is attributed to lower off-farm employment rates and an older age than census data. Additional observed data points of interest were spouse off-farm employment rate (54.3%), participation in Federal or State conservation incentive payments rate (31.6%), and whether some form of cattle enterprise was a part of the farmer's operation (51.5%). This data can be viewed in aggregate in Table 3-2.

Table 3-2: South Dakota Farmer Characteristics -Overall

Age	59.45 years	Owned Acres	1353.6
Off farm employment	22.5%	Rented Acres	1322.2
Spouse off farm	54.3%	Cropland Acres	1905.4
Years Primary dec	30.5 years	Pasture Acres	600.5
Raise Cattle	51.5%	Hay Acres	108.8
Federal/State Conservation Incentive Payments	31.6%	Federal Conservation Program Acres	52.3
		Average Farm size (Acres)	2667.1
Gross Income	%	Education	%
Less than $149,999	15.6%	Less than High School/GED	3.0%
$150,000-$399,999	19.6%	High School/GED	28.9%
$400,000-$749,999	17.9%	Some College	22.3%
$750,000-$1,499,999	26.8%	Occupational/Associates Degree	13.7%
$1,500,000-$2,499,999	11.2%	Bachelor's Degree	26.9%
$2,500,000 or Greater	8.9%	Graduate/Professional Degree	5.1%
Gross Income Average Score	3.20	Gross Education Average Score	3.47

Source: Author's Survey

Because of potential farmer reluctance and sensitivity of personal financial disclosures, this data was collected in the least invasive means possible, gross farm income. A scale was created with six increments, 1) $0-149,999, 2) $150,000-399,999, 3) $400,000-749,999, 4) $750,000-1,499,999, 5) $1,500,000-2,499,999, and 6) $2,500,000 or more. The overall mean score was 3.19, with category 4 have in the largest portion of farmers (26.8%). The total distribution of farmers is shown in Table 3-2.

Education data was also collected in a similar manner. Again, a scale was created with six increments, 1) Less than High School/GED, 2) High School/GED, 3) Some College, 4) Occupational/Associate Degree, 5) Bachelor's Degree, and 6) Graduate/Professional Degree. The overall average score was 3.45, with category 2 having the largest portion of farmers (28.9%) followed by category 4 (26.9%). The total distribution is shown in Table 2.

Overall adoption rates for PAT variables were, YM (68.7%), GPS (76.3%), and VRT (50%). This adoption pattern follows a similar pattern described by the literature, with sequential adoption of technologies in the perceived greatest overall value to the farmer (Schimmelpfennig and Ebel, 2016, and Schimmelpfennig, 2016). Adoption rates for other PATs were: autosteer (73.2%), automatic section control (54.5%), grid soil sampling (43.9%), prescription field maps (50.5%), aerial/satellite imagery (30.8%), and crop tissue sampling (37.4%). These adoption rates may be higher than aggregate adoption rates for various reasons. One reason may be that the average farm size was larger than USDA estimates. Because farm size is noted as a factor for PAT adoption, it is likely having a larger size farm would contribute to a higher adoption rate. Another reason could be the lower number of farmers who had off-farm employment in our survey (22.5%), which would imply a greater number of farmers with farming as their primary occupation.

There were three conservation agriculture (CA) practices primarily focused on in this study, diverse crop rotation (DCR), cover crop use (CC), and no-till and/or strip-till (NTST). DCR data was collected by first asking whether the farmer used a crop rotation, and second, what was their rotation. Not surprising, 93.4% of the respondents listed using a crop rotation. A variable was created to capture farmers that had a rotation greater than two crops, which was labeled a “diverse crop rotation” (DCR). Using the DCR variable, the percentage of farmers using more than two crops in a rotation dropped to 35.9%. Wheat was the most common third crop (26.3%) followed by alfalfa (4.5%). The percentage of farmers using CC was at 31.3%. Of those who used CC, 64.5% grazed the CC that season. Again, with NTST, a dummy variable was created to capture the use of both farming methods. Because both practices promote minimal soil displacement, it seemed appropriate to capture the use of one or both into one variable. Also, the use of no-till, strip-till, and the other farming practices were not treated as mutually exclusive acts. If the farmer used NTST and another practice, they were still counted as a NTST adopter. Using these criteria, 55.5% of the survey respondents the use of NTST in their operation.

<u>Farmer Characteristics by Practice</u>

For further analysis of farmer characteristics, using seven different variables, farmers were split into two groups, adopters or non-adopters, for each of the seven variables. The seven variables include three PAT variables (YM, GPS, and VRT) and three CA variables (TCR, CC, NTST) plus one for participation in the Conservations

Stewardship Program (CSP). Capturing any variations in the general statistically significant differences between adopters and non-adopter would allow for a further focused analysis on these areas. This analysis strictly looks at the arithmetic mean as a method of identifying potential trends for further analysis. The aggregation of the data can be viewed in Tables 3-3 and 3-4

Precision Agriculture Technology (PAT) Adoption

Table 3-3. South Dakota Farmer Characteristics - PAT (Means)

		Yield Monitor		GPS Guidance		Variable Rate Technologies	
	Overall	Yes	No	Yes	No	Yes	No
Age (Years)	59.45	58.37	61.79	58.82	61.65	57.21	61.72
Off farm employment	22%	17%	33%	19%	34%	20%	24%
Spouse off farm	54%	53%	57%	51%	64%	56%	52%
Primary Decision Maker (Years)	30.50	29.54	32.24	30.49	31.13	29.01	31.85
Raise Cattle	52%	48%	59%	53%	48%	46%	58%
Cow/Calf	46%	42%	52%	47%	45%	40%	49%
Federal/State Conservation Incentive Payments	32%	31%	33%	33%	26%	44%	19%
Owned Acres	1353.57	1445.00	1166.53	1522.85	825.84	1492.27	1223.58
Rented Acres	1322.16	1629.12	663.35	1554.52	570.37	1707.41	948.04
Cropland Acres	1905.45	2316.71	1022.99	2223.67	893.38	2356.74	1471.40
Pasture Acres	600.52	575.51	648.41	680.39	370.52	709.93	488.46
Hay Acres	108.83	105.65	115.72	112.88	95.60	93.45	124.34
Federal Conservation Program Acres	52.31	64.39	28.08	61.77	22.72	71.27	34.81
Average Farm size (Acres)	2667.10	3062.26	1815.20	3078.71	1382.22	3231.39	2119.02
Gross Income			Percent of Each Answer				
Less than $149,999	16%	7%	34%	9%	35%	6%	26%
$150,000-$399,999	20%	13%	31%	16%	30%	17%	21%
$400,000-$749,999	18%	18%	19%	17%	20%	16%	20%
$750,000-$1,499,999	27%	39%	3%	34%	7%	39%	16%
$1,500,000-$2,499,999	11%	13%	8%	13%	7%	8%	14%
$2,500,000 or Greater	9%	11%	5%	11%	2%	15%	3%
Score	3.20	3.61	2.37	3.50	2.26	3.62	2.79
Education			Percent of Each Answer				
Less than High School/GED	3%	4%	2%	3%	4%	2%	4%
High School/GED	22%	29%	28%	29%	29%	32%	26%
Some College	30%	25%	18%	25%	15%	22%	23%
Occupational/Associates Degree	14%	11%	20%	15%	10%	12%	15%
Bachelor's Degree	27%	26%	28%	24%	35%	29%	25%
Graduate/Professional Degree	5%	5%	5%	5%	6%	3%	7%
Score	3.48	3.43	3.59	3.42	3.63	3.43	3.53

Source: Author's Survey

Yield Monitor (YM) Adoption

Overall YM adoption was 68.7%. Using the same descriptive methodology as before, farmers who adopted YM were about 3.4 years younger than those who did not adopt YM (58.4 vs. 61.8). They were also nearly half as likely to have off-farm employment (17.3% vs. 32.8%), and less likely to have cattle. Additionally, their farm size was greater than non-adopters, with more than double the cropland (2,316.7 vs. 1,023 acres) while having less pasture and hay ground. The gross farm income score was significantly higher (3.61 vs. 2.37), again showing increased size was a determinant of the adoption of YM. The education level score was lower for YM adopters than non-adopters (3.43 vs. 3.59) implying education level may have a negative effect on YM adoption.

Global Positioning System (GPS) guidance systems Adoption

Overall GPS adoption rates for the farmer as operator was 76.3%. The average age of the adopter is lower (58.8 vs. 61.6). Again, off-farm employment for adopters was nearly half as likely (19.3% vs. 34.0%). GPS adoption was the only PAT that had a higher likelihood of a cattle operation. Farm Size for adopters was also larger (3,078.7 acres vs. 1,382.2). Cropland acres for GPS adopters was nearly 2.5 times as larger than non-adopters (2,223.7 vs. 893.4 acres). Gross farm income scores were again higher for adopter and again education scores were lower than non-adopters.

Variable Rate Technologies (VRT) Adoption.

Overall VRT adoption was 50%. Again, the average age of the adopter was younger than the non-adopter (57.21 vs. 61.72). The age difference was the greatest of all six PAT and CA practices evaluated using this method. Off-farm employment was lower for adopters versus non-adopters and raising cattle lower for adopters as well. An interesting finding was that VRT adopters were over twice as likely to have some sort of Federal or State Conservation Incentive payment. The largest federal or state conservation incentive program farmers were involved in was CSP, in which 78.6% of the adopters stated they were involved in the program. Average acres were again higher for VRT adopters, however VRT had the smallest gap between adopters and non-adopters for cropland (2356.7 vs. 1471.4 acres) and pasture land was greater for adopters as well (709.9 vs. 488.5 acres). Gross farm income was again higher for VRT adopters, but the gross farm income score gap was the smallest of the three PATs, less than 1. This implied that greater income levels are less likely to adopt this practice than other PATs, which has been found in the literature (Schimmelpfennig and Ebel, 2016). The education level score is again lower for adopters than non-adopter (3.43 vs. 3.53), but with the smallest score gap of all three PATs (<.1).

All three PATs displayed similar patterns of adoption, with slight variations in each. The overall trend was that farmers who adopted PATs were slightly younger, were less likely to have off farm income, farmed more overall and crop acres, had higher gross farm income levels, and had slightly lower levels of education. This statistical analysis allowed us to better formulate the modeling for further analysis.

Conservation Agriculture (CA) Adoption

Table 3-4. South Dakota Farmer Characteristics – CA (Means)

		Diverse Crop Rotation		Cover Crops		No Till/Strip Till	
	Overall	Yes	No	Yes	No	Yes	No
Age (Years)	59.45	61.01	58.55	58.19	60.04	58.65	60.47
Off farm employment	22%	10%	29%	13%	27%	20%	25%
Spouse off farm	54%	51%	56%	56%	53%	52%	57%
Primary Decision Maker (Years)	30.50	29.52	31.00	28.33	31.50	29.20	32.38
Raise Cattle	52%	63%	45%	65%	46%	57%	44%
Cow/Calf	46%	61%	44%	67%	26%	57%	42%
Federal/State Conservation Incentive Payments	32%	32%	31%	49%	23%	42%	19%
Owned Acres	1353.57	1867.00	1063.74	2043.82	1037.00	1556.97	1108.57
Rented Acres	1322.16	1494.61	1226.19	2019.22	1007.69	1734.94	829.63
Cropland Acres	1905.45	2412.40	1622.03	2725.10	1531.78	2296.64	1416.46
Pasture Acres	600.52	680.46	556.11	1153.71	344.57	792.55	354.91
Hay Acres	108.83	157.01	82.62	160.99	84.72	122.27	92.45
Federal Conservation Program Acres	52.31	94.57	28.98	99.79	30.53	63.75	38.53
Average Farm size (Acres)	2667.10	3344.43	2289.75	4139.59	1991.60	3275.20	1902.35
Gross Income			Percent of Each Answer				
Less than $149,999	16%	6%	21%	5%	20%	11%	21%
$150,000-$399,999	20%	17%	21%	18%	20%	15%	25%
$400,000-$749,999	18%	15%	19%	18%	18%	21%	14%
$750,000-$1,499,999	27%	30%	25%	23%	29%	32%	21%
$1,500,000-$2,499,999	11%	26%	3%	21%	7%	12%	10%
$2,500,000 or Greater	9%	6%	11%	16%	6%	8%	10%
Score	3.20	3.66	2.93	3.84	2.90	3.33	3.04
Education			Percent of Each Answer				
Less than High School/GED	3%	6%	2%	2%	4%	3%	3%
High School/GED	22%	30%	29%	24%	31%	22%	38%
Some College	30%	25%	21%	21%	23%	30%	13%
Occupational/Associates Degree	14%	10%	16%	11%	15%	14%	14%
Bachelor's Degree	27%	23%	29%	35%	23%	27%	27%
Graduate/Professional Degree	5%	7%	4%	6%	4%	5%	6%
Score	3.48	3.35	3.55	3.74	3.36	3.53	3.41

Source: Author's Survey

Diverse Crop Rotation (DCR) Adoption

Overall DCR adoption rates were 35.9% of the farmer respondents. DCR was the only practice that had a higher mean age of adopters than non-adopters (61 vs. 58.6 years). Adopters were also 1/3 less likely to have off-farm employment (10.5% vs 29.2%). DCR adopters were also more likely to have cattle. DCR adopters also tended to own more acres, have more acres in cropland, and have more overall acres than non-adopters (3,344.4 vs. 2,289.7 acres). The gross farm income score was also higher (3.66 vs. 2.93) which correlates with a larger farm size. The education score was lower for adopters than non-adopters with the lowest average score of all practices at 3.35.

Cover Crop (CC) Adoption

Overall CC adoption rates were 32.1% of our farmer respondents. CC adopters had a slightly lower mean age compared to non-adopters (58.2 vs. 60.0 years). Off-farm employment for CC adopters over was less than half of non-adopters (12.5% vs 26.7%). CC adoption also showed a higher mean of cattle raisers (64.5% vs. 45.6%), and a very wide gap between cow/calf operators (67.2% vs. 26.3%). They also were over twice as likely to have some sort of Federal or State Conservation Incentive payment (49.2%). Of these CC adopters, 80% were involved in CSP. CC adopters were more like to own land by the largest margin (1,006.8 acres) of any of our groups (2,043.8 vs. 1,037 acres), owning twice as much land as non-adopters. CC adopters also had the largest amount of cropland (2,725.1 acres), pasture land (1,153.7 acres), and overall acres (4,139.6 acres) of any of the practices. They also had the highest gross farm income score (3.84) and the highest education score (3.74). It should be noted that the survey only asked if they were using cover crops, not on how many acres. Conceptually, it would make sense that larger farms with more owned cropland and a higher gross farm income would be more willing to try cover crops due to less risk being spread out over more acres and more time available because they are less likely to have off-farm employment. Also, with cover crop adoption benefits generally being long term, having control of the land through ownership should make a farmer more willing to try the practice versus a farmer who rents a higher proportion of their land (Lichtenberg, 2001).

No-till and/or Strip-till (NTST) Adoption

Overall NTST adoption rates were 55.5% of our farmer respondents. Mean age for NTST adopters was slightly lower (58.7 vs. 60.5) and off-farm employment was also slightly lower (20.2% vs 25.3%). NTST adopters raising cattle was again higher, but lower than the other conservation practices at 56.9%. Federal or State conservation incentive payments for NTST adopters were also higher (41.5% vs 19.0%), again over twice as high as non-adopters. Farm size was also larger with NTST adopters, with overall higher acre amounts in all individual categories and average farm size (3,275.2 vs. 1902.3 acres). The gross farm income score had the smallest gap of any of the practice adopters (3.33 vs 3.04). The education score was also higher for NTST adopters than non-adopters (3.53 vs. 3.41).

Overall, regarding conservation practices, a theme emerged across CA practices for adopters of having less off-farm employment, being more likely to raising cattle in some form, higher Federal or State conservation incentive programs, larger farm size with more acres owned, and higher gross farm income scores. The education score was dependent on the practice. Intuitively, this makes sense, with farmers deciding to diversify through off-farm employment or raising livestock. Also, it is not surprising that farmers with more off-farm income would farm less acres, in which a negative correlation was observed. The data shows that gross farm income was larger across all adopters of these conservation practice. This leads to an overall positive correlation between adopting a CA or PAT practice and farm size, gross farm income, and not having off-farm employment.

A cross tabulation table (Table 3-5) was created to show the likelihood of adoption of one practice dependent on another practice. This table looks at how the adoption of one practice affects the adoption of another practice. A pattern emerges of a bundling factor, where the likelihood of adoption of one practice increases the likelihood of another practice. This can be seen with PATs, where if one PAT practice is adopted, another PAT has a higher adoption rate. This pattern was not seen in CA practices as much but adopting NTST did increase the likelihood of adoption of all other practices.

Table 3-5. Cross Tabulation of Adoption Rates of PAT and CA Practices

	Practice	YM		GPS		VRT		NTST		DCR		CC	
Practice	Adoption	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
YM	Yes	100%	0%	94%	6%	64%	36%	61%	39%	37%	63%	31%	69%
	No	0%	100%	34%	66%	19%	81%	42%	58%	34%	66%	31%	69%
GPS	Yes	85%	15%	100%	0%	60%	40%	63%	37%	37%	63%	33%	67%
	No	15%	85%	0%	100%	17%	83%	32%	68%	32%	68%	26%	74%
VRT	Yes	87%	13%	90%	10%	100%	0%	62%	38%	34%	66%	35%	65%
	No	49%	51%	60%	40%	0%	100%	47%	53%	37%	63%	26%	74%
NTST	Yes	75%	25%	86%	14%	56%	44%	100%	0%	40%	60%	41%	59%
	No	27%	73%	28%	72%	19%	81%	0%	100%	14%	86%	9%	91%
DCR	Yes	70%	30%	79%	21%	48%	52%	62%	38%	100%	0%	44%	56%
	No	68%	32%	74%	26%	51%	49%	52%	48%	0%	100%	24%	76%
CC	Yes	69%	31%	81%	19%	58%	42%	73%	27%	50%	50%	100%	0%
	No	68%	32%	74%	26%	46%	54%	81%	19%	29%	71%	0%	100%

Source: Author's Survey

Independent Variables

Seven variables were chosen as independent variables to analyze the PAT and CA adoption practices. Several are straightforward characteristics of the farmer such as age, education, off-farm income, cropland acres, and cattle. These variables were discussed in the above descriptive data. Two additional variables, highly productive land and the Conservation Stewardship Program were used to help define adoption practices in South Dakota. A description of each is provided below to better understand their importance.

Highly Productive Land Variable

South Dakota topography and soil quality change throughout the state. To capture the difference in quality of cropland, a highly productive land (HPL) variable was created. To create this variable, data was collected from NASS on non-irrigated cropland cash rent paid per acre on South Dakota Farms in 2016 (NASS, 2017). A threshold of $170 per acre county average was set, with any county at or above this point being considered "highly productive land". This threshold was an arbitrary value set by the researchers as a starting point to distinguish land quality as a proxy for data on individual parcels. Further analysis is needed to better understand the relationship between land quality and conservation practices.

Conservation Stewardship Program in South Dakota

The Conservation Stewardship Program (CSP) is a conservation program approved in the 2008 Farm Bill that pays farmers to build on existing conservation efforts while encouraging and implementing new conservation enhancements to their operation (USDA, 2018). The contracts last five years and farmers are eligible for the program if they are already doing some conservation practice on their farm, such as crop rotations, riparian buffers, and minimal or no-till, and payments are received for “enhancements” the farmer is willing to implement on their operation. Enhancements can range from increased use of precision technologies such as YM, GPS, and VRT for fertilizer and herbicide applications, among other uses, and conservation practices such as reduced tillage practices, cover crop use, split nitrogen application, and more diverse crop rotations. It also promotes other conservational practices such as intensive rotational grazing and pollinator habitat.

South Dakota has seen a steady increase in CSP participation. The decrease in new contracts may reflect farmers who completed their first 5-year contracts and were either not eligible or not interested in signing up into a new contract. As of 2016, there were 2,881 total South Dakota farmers were enrolled in CSP with an average yearly payment of $26,722.08, with 6,876,330 acres enrolled with an average payment $11.19/acre. (Table 3-6)

Table 3-6. Conservation Stewardship in South Dakota

Program Year	1	2	3	4	5	6	7	8
Calendar	2009	2010	2011	2012	2013	2014	2015	2016
Number of Active Contracts	0	505	330	310	404	592	898	677
Total Acres on Active Contracts	0	1,294,390.50	868,844.00	845,869.80	984,965.60	1,276,039.60	2,122,019.80	1,647,436.50
CSP Technical Assistance Obligations by Fiscal Year	$184,000	$ 1,457,300	$ 2,913,400	$ 2,626,100	$ 3,529,100	$ 4,610,200	$ 5,594,200	$ 16,188,800
CSP Financial Assistance Obligations by Fiscal Year	$ -	$ 14,874	$26,396,800	$35,816,100	$46,773,500	$ 61,524,200	$ 70,156,600	$ 76,986,300
CSP Total Obligations by Fiscal Year	$184,000	$ 1,472,174	$29,310,200	$38,442,200	$50,302,600	$ 66,134,400	$ 75,750,800	$ 93,175,100

Source: Natural Resources Conservation Service- Washington- DC. 31 May 2017.

CSP Adoption

As per our survey data, the number of farmers involved in CSP was 42 or about 21.2%. Farmers involved in were on average 56.0 years of age compared to 60.4 years for non-CSP farmers. The likelihood of off-farm income was higher with CSP farmers (26% vs. 21.5%). Those involved with CSP were also slightly less likely to raise cattle (47.6% vs. 52.6%). CSP farmers owned more land than non-CSP farms, while having more rented acres, more cropland acres, less pasture acres, and more overall acres. The gross farm income score was higher as well (3.71 vs. 3.12) and the education score was higher as well (3.76 vs. 3.40).

Conceptual Model

There are many variables in work in the analysis. There are two general agricultural production practice categories being analyzed, PAT and CA, and each category contains three sub-categories of practices. Additionally, seven independent variables are used in the model to measure the marginal effect on adoption. This is done using two methods, the multinomial logit and the bivariate probit models. However, the rational for these variables needs to be further evaluated to better understand the use of the two models. In this section, PAT and CA will be evaluated separately, then together, to explain the theorized relationship of the variables.

Precision Agricultural Technologies

PAT practices tend to be longer term investments for farmers due to their higher costs. The three practices focused on in this study were YM, GPS, VRT. These higher costs can be mitigated through increased production, higher yields or increased ability to farm more acres, or decreased total variable costs. Because farmers act in a near perfectly competitive market, the theory of the firm is best used to help describe production decisions. The goal of the firm is to maximize profits through a combination of output and input decisions.

By increasing production through yields, farmers can increase revenue if marginal cost (MC) does not exceed marginal revenue (MR). If the farmer chooses to increase production by volume through increased acres, average total cost (ATC) falls with lower average fixed costs (AFC) decreasing the MC per unit. The third option is to decrease average variable cost (AVC) more than the AFC to lower the ATC through better use of inputs. For example, if the purchase of a PAT increases AFC, but then lowers the AVC, by using less inputs, below the original ATC without changing production output, a farmer would want to adopt this practice. Therefore, farmers can take different approaches to how they adopt PAT. Some may choose to purchase the equipment outright, justifying the purchase through production increases. Other may choose to custom hire these practices, to mitigate risk and because they cannot justify the cost for owning the equipment in their operation.

Given these assumptions, some of the independent variables should align with this theory. HPL and cropland acres should both positively effect adoption by fulfilling the higher production needed on a per unit and overall basis. More acres and better production should lower ATC per unit from either a lower AVC or AFC. Operations with cattle may also see a positive effect on adoption rates due to lower costs of inputs from fertilizer from cattle waste, lowering their cost structure. CSP should also have a positive effect on adoption as well for the same reason. CSP incentivizes the adoption of PAT through payments to adopt the technology. This increase subsidy payment effectively lowers or neutralized any increase in AFC while lowering AVC, resulting in a lower ATC.

The last three independent variables, off-farm employment (OFE), age, and education, are focused more on the individual than the operation. OFE income can be looked at through two lenses. The first is OFE indicates a farmer may not be able to farm full time, therefore requiring another job to pay for some living expenses or to help subsidize the farming operation. This could be because of their farm's size or their farm's production abilities. Since these are both important to the cost structure of production, they may have a higher cost of production which they would not see the benefit over a reasonable amount of time to justify the increase in AFC to the decrease in AVC. The payback period would be too far out. Also, because none of these practices are a time saver for the farmer, the farmer with OFE cannot justify the practice on a time efficiency measure. However, OFE could be viewed as a form of subsidy for the farmer to help the farming operation. If the farmer chooses to take earnings from off the farm to use, even at a loss personally, for the use of PATs, it lowers the TFC, and therefore the AFC and ATC for the farm, making it a viable choice.

Education and age are more straightforward. With the adoption of PATs being a somewhat progressive act, one would think that with a higher education level would come a higher adoption rate. However, farming is an occupation that does not require a degree. Several respondents had below a high school education. There were also several that had advanced and professional degrees. With the average age of a farmer from the survey being 59.5 years of age, education may not have as large of an impact on adoption rates. With age, there is also a dichotomy of thought. As the farmer ages, he may be less likely to spend at levels he would have at a younger age. Adding additional assets, and therefore costs, may not provide the required rate of return over the farmers career horizon. The adage “One in the hand is worth two in the bush” applies here. However, with age tends to come greater wealth through increased cash flow and accumulated wealth. Like the farmer with OFE, they may choose to adopt PAT by subsidizing it with increased available cash or lower AFC (i.e. owned land versus rented, lower overhead costs, etc.). Both are viable directions a farmer may choose to go in that stage of their farming career.

With all of these independent variables, besides evaluating adoption rates individually, they are also looked at sequentially. As stated in the literature review, PATs are expected to be added sequentially and stacked, having one technology benefiting adding another (Daberkow and McBride, 1998, Schimmelpfenning, 2016). An example is having a YM, then adding GPS to record the yield at each point within the field, then adding a VRT planter or fertilizer spreader to place the proper amount of input on the field to reduce input costs. Without adopting the previous technology, each sequential addition is less effective and almost requires the previous technologies. Therefore, “bundling” is more prevalent. Without total adoption, the maximum benefit is not realized. Because of this, the expectation is that most adoption patterns for the dependent variables will follow this sequential adoption pattern.

Conservation Agriculture

Conservation Agriculture (CA) adoption is different than PAT adoption in that advantages of adoption vary among practices. With PAT, adoption is dependent on productions efficiency that can be easily measured, such as more or less fertilizer in a specific area. PAT is also more data driven, through collection and analysis of data, and results can be realized within a cropping year. CA practices differ from this. CA adoption is a long-term strategy because the benefits of the practices generally are not realized in the first years of adoption. For example, if cyst nematodes are prevalent in a field, the use of CC or DCR can help reduce pest pressures on a field, but it will take several years to see the results. It becomes difficult to directly tie an expense today to an unseen benefit in the future. CA adopters also tend to be more conservation minded, wanting to preserve their livelihood as well as their way of life. Of the three practices focused on, NTST is probably the closest to a PAT in that you can see the reduction in fuel and tillage costs the first year. DCR and CC are more difficult because they require a multi-year approach. Unlike the PAT practices, these CA practices cannot be lumped together and should be evaluated on an individual basis.

NTST adoption is a practice that minimizes or eliminates tillage. The main reasons why a farm would want to adopt this practice is to conserve water, reduce or eliminate costs associated with tillage, and reduce inputs over time. By not breaking up the ground, water is preserved in the soil by minimizing surface area contact with the air. This is best for soils with a lower ability to hold moisture and that does not receive adequate precipitation through the year. Beyond moisture retention, there are reduced costs from less fuel intensive passes over the field from tillage. Another advantage to long-term NTST use is reduced input costs. A study of a South Dakota no-till farmer showed a 25% decrease in nitrogen use and a 30% in phosphorus fertilizer from 1990 to 2013 for his corn crops, while increasing his yields nearly 120% over that same period (Anderson, 2015).

Research on the NTST yield and economic impacts are mixed. A study in South Dakota focused on the economic analysis of no-till rotations and effects on carbon sequestration with data from 2001-2008 found greater returns to a conventional tillage system with a corn and soybean rotation than a comparable no-till system of corn and soybeans (Janssen and Harer, 2010). However, a 2016 report out of Kansas found yields for corn, soybeans, and overall wheat from 2010-2014 were higher across all crops for NTST (Ibendahl, 2016). Another report from South Dakota in 2018 reporting yields for the corn and soybean high-yield contests reported similar yields for corn (NTST 275.4 bu. versus CT 266.5 bu.) and soybeans (NTST 72.2 bu. versus CT 74.1) (Bly et al, 2018).

In this study, NTST yields for corn in 2016 were 162 bushels per acre compared to 173.5 bushels for conventional tillage. NTST soybeans yields were similar to CT, with yields in 2016 at 50.5 bushels per acre, compared to 51 bushels per acre under conventional tillage (Kolady and Deutz, 2018). Extending the profit maximizing theory used for PAT will tell if a farmer would adopt NSTS if the conservation of moisture and reduced fuel costs out weighted the cost of equipment. Production may play a factor in the decision, however from the survey data collected in 2016, the loss from corn (-11.5 bushels times $3.25 equals -$-37.38 per acre) may outweigh the cost of tillage. This leads to a potential mixed effect from yield differences in NTST and CT systems. Because of this, currently the choice of cropping system may be a moot point when it comes to yield benefits.

It could be the case that yields lagged for early adopters of NTST because they were first adopters. As equipment, knowledge, and the benefits of long-term adoption improved year after year, techniques improved and, so did the yields. Adoption is now looked at as a long-term investment, with upfront costs, but with a reasonable and improving payback period.

Over the last few decades, crop diversity is in decline in the upper Midwest. As farmers became larger and more specialized, they focused on fewer crops while either expanding or eliminating their livestock operations. Changes in crop insurance and the general agribusiness infrastructure have favored the expansion of corn and soybean acres. Livestock operations have also switched to utilizing more corn and soybean feedstuffs, particularly dried distillers grain with solubles (DDGS) and soybean meal. At the same time, wheat production has decreased along with oats and other small grains. Farmers historically raised some small grain for straw bedding and feed. It also spread out their workload through the year, having different planting and harvest dates than corn and soybean, and it also gave them an area to spread manure in the summer from their livestock. As fewer farmers raised livestock and the use of straw was greatly reduced or eliminated by the growth of concentrated animal feeding operations (CAFOs), the need for small grains on many farms has diminished. Farms also reduced the amount of hay (alfalfa and grass) to cattle, beef and dairy, and increase the use of corn silage and grain corn by-products. Projected planting acres for the main small grain crop, wheat, is at roughly 46.5 million acres, the lowest acres in 99 years and down 20 million acres since 1998 (USDA, 2018). Wheat is the third biggest row crop grown in the U.S., but as other countries have increased production, the need for wheat in the U.S. has dropped, giving way to more corn and soybean acres.

Survey data from this study confirms this trend for sample counties. Data from the survey results in corn and soybean acres making up about 38% each of the total acres, all wheat making up 14%, hays making up about 5%, and the rest split between various other crops. As these percentages show, corn and soybeans are the dominant crops, with wheat a distant third. For the farmers that do have a DCR, corn and soybeans still dominate the rotation. Corn and soybeans acres are down to about 34% of total acres each, while wheat increases to about 23%. Another observation from the data helps understand why an additional crop may be used. Farmer's with a DCR had yields on corn and soybean acres of 160 and 47.5 bushels per acre, respectively. CT farmers had higher corn and soybean yields per acre, 172 and 53 bushels, respectively. The lesser yield could be looked at as a proxy for land quality. This is confirmed with looking at the

HPL dummy variable, which was twice as high (42%) for the 2-crop rotation as it was for the DCR (21%). From here we can postulate why a farmer may have a DCR. If the productivity of the land is limited by some factor (soil type and quality, precipitation, etc.), then from a profit maximization perspective, it might be advantageous to add a crop that can handle those conditions better. Additionally, studies have shown that increasing crop diversity in a rotation can increase productivity of other crops. In a long-term study from South Dakota, corn yields increased 52% by increasing a crop rotation from 2 to 5 crops (Anderson, 2015). This sounds great in theory, however, it is difficult to have both the equipment and a market for 5 different crops. Typical corn and soybean equipment needs to retro-fitted or new equipment altogether needs to be purchased to raise additional crops. Also, a market needs to be in place. South Dakota has done a good job creating a supply chain for these markets, but there is only so much demand for these other crops.

Beyond the marketing, just having additional crops can be a barrier to some farmers. The simplicity of two crops reduced the cost of limiting diversification and it also makes it easier to have off farm employment. From the survey data, farmers without a DCR (29.2%) were nearly 3 times as likely to have OFE as a farmer with a DCR (10.4%). This again makes sense. Having OFE would limit the available hours a farmer could spent working. DCR farmers also were more likely to raise cattle in some form. 63.4% of DCR farmers had cattle on their operation compared to only 44.9% for non-DCR farmers. It would be logical to assume that there is a negative correlation between having a OFE and not having cattle and having cattle and not have an OFE. The farmers with cattle obviously supplement their income with their cattle operation. Specific size of the cattle operations was not asked, so cattle could mean 10 cow and calf pairs or feeding 5,000 fat cattle. If more information was collected and thresholds were created for cattle, the percentage of non-DCR farmers with cattle would have dropped. Having cattle would also increase the likelihood for the need for hay acres, which would also contribute to a more diverse crop rotation.

The lowest adopted CA practice evaluated was cover crops. Cover crops are not a new practice, but they have seen a resurgence in the last decade. Historically, farmers would plant a cover crop to help hold the soil in place, build fertility for the next year and provide additional forage for livestock. It was well known among farmers that a crop rotation reduces the chances of a crop failure, and planting legumes, such as clovers, peas, and alfalfa, helps provide fertility for heavy nutrient use grain crops such as corn and soybeans. Grazing a field with livestock also helped break pest cycles and helped lessen the work load of storing and hauling in feed and removing and hauling out animal waste. Grazing a field with a cover crop gave the farmer an opportunity to do this and work with the nature's natural cycle.

Traditional farming practices, which included livestock integration, diverse crop rotations, and the use of fallow periods so the land could regenerate, started to change by the early mid-20th century. With the discovery that urea (derived from natural gas and air) manufactured in munition factories during World War I and II could be applied on fields to increase yields in crops, farmers began to use urea to increase yields of their high value crops, particularly corn and wheat. Now higher yields could be achieved without having to use fallow years, cover crops or grazing. Because this made it easier for farmers to farm, they could then specialize and increase their acres. USDA policies from the 1970 under Secretary of Agriculture Earl Butz, pushed farmers to modernize and industrialize, leaving historic practices, such as cover crops, left behind (Berry, 1977). Research was now being focused on chemical and agronomic factors in cropping systems, but not on the soil itself.

However, there has been a renewed focus on cover crops recently. Pockets of organic and traditional farmers as well as researchers have been keeping the practices going. With soil science researchers discovering more about our soils and how healthy soils work, they are finding plant diversity in a field helps improve the quality of the soil, much like NTST and DCR. CC improve the soils by choosing species that will add benefits to soil. For example, if more nitrogen is need, a legume can be added to fix nitrogen naturally. If there is a compaction issue in the field, daikon radish will create spaces in the soil down over 24” deep and over 3” in diameter and deteriorate by the following spring. If increases in organic matter are the goal, then annual rye grasses will add large amounts of root mass to the soil. Adding these prescribed plants to the soil also reduces the amounts of unwanted plants, weeds, by out competing them in the area. Recent research has been done showing the benefits of combining multiple cover crops species in a cover crop mix (Millborn Seeds, 2017). By using multiple species, it helps with all the aspects listed above, but also provides a synergistic effect, like mimicking the native prairies these soils were developed for over time.

With all the benefits of cover crops, there are also problems with implementation. Timing of the planting is difficult. With corn and soybeans, there is a small timeframe for establishing a CC after harvest because of the short growing season. Most CCs will not establish, and the benefits are reduced. Small grains provide an adequate timeframe for a

CC after harvest usually works well. The other option for CC establishment is to incorporate them during the growing season. This can be done by spreading the seed over the top or inter-seeding them into a standing crop. This can create problems, in soybeans especially, if harvest is wet and delayed allowing the CC to establish well in the crop and interfere with harvest. Another problem is herbicide application. With most corn and soybeans being genetically modified, they inherently have herbicide tolerance. However, with the use of some residual herbicides, they can last in the soil for over a year at rates sensitive to some CC species. This limits the available herbicides a farmer can use on their operation and requires greater planning to make CCs work properly.

There is also the issue of uncertain economic return. CC seed can cost anywhere between $10 and $50 per acre, plus seeding costs with no direct cash flow in the first year. The use of cover crops is a long-term strategy for rebuilding soil health. Also, it may be difficult to analyze the financial benefit in CCs like the use of a certain seed or chemical in a crop year. CCs benefits build over time and are released over time. Farmers, such as Gabe Brown and Jerry Brandt, have reported lower input cost from increased organic matter in the soil resulting in higher amounts of nutrients available, as well as increased water retention. However, this was realized after many years of CC use, coupled with NTST and DCR (Montgomery, 2017). Our survey data suggest that government incentives may play a role in cover crop adoption. Farmers who adopted CCs were more than twice as likely to be involved in some sort of government program (49.2%) versus a non-CC adopter (23.3%), with the overall average being 31.6%.

With these barriers to adoption, farmers are less willing to adopt CCs. From the survey, only 32% of famers stated they used cover crops in 2016. It was not asked on how many acres, so use could vary and does not encompass all their acres. Also, with most farmers renting land on a year to year basis and tight profit margins, they would be less likely to invest long term in the use of cover crops on land they may not rent in the future. Survey data supports this theory, with the average farmer who adopts CCs owning twice as many acres (2,043) as the farmer who does not use cover crops (1,037). The logic makes sense, farmers who own their land are more concerned about the well-being and legacy of their land and may choose to take care of it better, where a farmer renting the farm year to year does not have a long term vested interest in the land.

Livestock integration may play a role in this decision as well. CC also provides an opportunity for late season forage as well as early season forage the following year. For example, a CC following a small grain provides an opportunity to grow more than 2 tons of dry matter per acre of forage for grazing cattle (Sexton, 2017). With a grazing forage utilization rate of 50% while using a proxy price of $100 per ton for grass hay, grazing CCs could gross as much as $100 per acre in feed (Kolady and Deutz, 2017). Other benefits would be less machinery and fuel costs for feeding and hauling waste, healthier cattle from grazing and cleaner conditions than a confined area, and improved soil health from cattle processing and incorporating the forage back into the soil. For spring forage, the CC may be used in spring calving, providing a clean place for the cow and her young calf, or for chopped forage or hay before a cash crop, such as soybeans. Survey data also supports this theory, with CC adopters having higher rates of cattle (64.5%) than non-CC adopters (45.6%). The difference is more striking for cow/calf operations, with 67.2% of CC adopters having a cow/calf operation, while only 26.3% of non-CC adopters had cow/calf operations.

In conclusion, there are many theoretical reasons for CA adoption among these practices. NSTS adopters, in theory, focus on cost saving, soil moisture preservation, and potentially increased crop yields. DCR adopters look at long-term benefits, contributing to soil health and multi-year profit maximization, from improved crop yields and diversification from livestock. CCs improve soil health, and helps livestock operators increase forage production and profits, but tangible profits are hard to evaluate currently. All of these CA practices have a common thread of improving soil health as a major goal, which is different from PAT adoption which is primarily profit maximization driven.

The Link Between PAT and CA Practices

The conceptual link between PAT and CA practices are rather straightforward. Given that, in some form, all these practices are driven by profit maximization, adoption will be driven by this as well. However, how a farmer interprets the profit maximization on their farm will be different. Some farmers will see value in practices that other will not. These decisions will be made by the characteristics of the farmer's operation. Farmers ought to adopt PAT and CA practices if they improve their bottom line or improve the efficiency of their farming operations. If the assumption is that all these practices can attribute positive benefits to their farms, which was shown above, then there should be a positive correlation between PAT and CA. Furthermore, since PAT practices can help lead to the use of less inputs, conserving, then CA adopters should want to adopt this as well if conservation is a motive for adoption.

Empirical Model

Multinomial Logit Model

A multinomial logit model has been employed that uses a random utility framework to answer the underlying question of farmer's adoption decision. Multinomial logit model is a utility model with alternative choices which are unordered but are considered mutually exclusive. The model assumes that the farmer chooses the alternative that maximizes his or her utility from the set of alternatives.

When it comes to conservation practices, farmers in our sample can choose from a set of eight conservation choices/bundles resulting from the various combinations of no-till/strip till (NTST), true crop rotation (TCR), and cover crops (CC). The mutually exclusive choice set includes: adoption of CC only; adoption of TCR only; adoption of NTST only; adoption of CC and TRC; adoption of CC and NTST; adoption of NTST and TCR; adoption of CC, TCR, and NTST; and none.

Following McFadden (1974), the utility function for the farmer can be specified as follows:

$$\mathrm{V}ij = \mathrm{X}ij\beta + \varepsilon ij \qquad (1)$$

where $\mathrm{V}ij$ is the utility for farmer i choosing conservation bundle j, $\mathrm{X}ij\beta$ is the observed component, εij is the unobserved component of the utility function, and $\mathrm{X}ij$ is the vector of covariate variables which are assumed to be linear. Farmer i will choose conservation bundle j subject to the following constraints:

$$\mathrm{V}ij \geq \mathrm{V}ik \quad for \text{ all } j \neq k$$

(2)

$$\mathrm{X}ij\beta + \varepsilon ij \quad \geq \quad \mathrm{X}ik\beta + \varepsilon ik$$

(3)

The probability of farmer i choosing conservation bundle j can be defined as follows:

$$\mathrm{P}_{\mathrm{ij}} = \frac{e\ Vij}{\sum_{j=1}^{J} eVij}$$

(4)

Since the dependent variable "conservation bundle" has eight choices, it requires the calculation of seven equations, one for each category relative to the reference category, to describe the relationship between the dependent variable and independent variables. The multinomial logit model was used to understand farmers' precision technology adoption decisions as well. For this study, there was a focus on three precision technologies; GPS, VRT, and YM. As in the case of conservation practices, farmers can choose from one of the eight mutually exclusive choice sets: GPS only, VRT only, YM only, VRT&GPS, VRS &YM, YM&GPS, VRT, GPS, &YM; and none.

The MNL model calculates seven predicted log odds, one for each category relative to the reference category. Interpreting coefficients of MNL model is complicated, hence marginal effects are calculated to understand the impact of a relative change in the conditional mean of a particular choice with respect to the independent variables.

Bivariate Probit Model

When it comes to choosing among conservation practices and precision technologies, we can model farmers' adoption as two separate dichotomous decisions, where the disturbance terms of the two equations are likely to be correlated; that is, some unobservable characteristics captured in the error term of the precision adoption equation are likely to influence the error term in the adoption of conservation adoption equation. Hence, we employ a bivariate probit model to include the two dichotomous decisions and the potential correlation between them. Use of the bivariate probit model helps us to analyze whether farmers behave differently when it comes to precision technologies and conservation practices. The details of the model are given below.

To examine the potential correlation between these dichotomous decisions, the farmer's decision process is modeled using the random utility framework. From the utility theoretic standpoint, a farmer is willing to adopt a new technology/practice if the farmer's utility with the new technology/practices, minus its cost, is at least as great as the old technology/practices—that is, if

$U(1, Y_1 - C; \mathbf{X}) \geq U(0, Y_0; \mathbf{X}),$

(1)

where 1 indicates the new technology/practice and 0 the conventional alternative. Y_1 and Y_0 are expected profits from new and old technologies, respectively; C is the price to be paid for the new technology by the farmer; and $\mathbf{X}$ is a vector of independent variables.

The farmer's utility function $U(i, Y; \mathbf{X})$ is unknown to the researcher, and the deterministic part of the utility function is $V(i, Y; \mathbf{X})$, so the inequality can be written as

$V(1, Y_1 - C; \mathbf{X}) + \upsilon_1 \geq V(0, Y_0; \mathbf{X}) + \upsilon_0,$

(2)

where υ_1 and υ_0 are independently and identically distributed random disturbances with zero means and unit variances.

The decision model to predict the probability of adoption of precision technology is discussed below. Let

$Y_1{*}= \beta_1'\mathbf{X}_1 + \upsilon_1,$

(3)

where $\beta_1'\mathbf{X}_1 = V(1, Y_1 - C; \mathbf{X}) - V(0, Y_0; \mathbf{X}) = V^1 - V^0$,

$Y_1 = 1$ if $Y^*_1 > 0$ (adopted precision technology, that is any one of the three precision technologies), and $Y_1 = 0$ otherwise (not adopted any precision technology). V^1 stands for deterministic part of utility from adopting precision technology, V^0 stands for that from status quo, and υ_1 is the disturbance term in Equation 3.

Let

$$Y_2^* = \beta_2'\mathbf{X}_2 + \upsilon_2, \tag{4}$$

where $\beta_2'\mathbf{X}_2 = V(\text{Conservation}, Y_{\text{conservation}} - C; \mathbf{X}) - V(\text{nonconservation}, Y_{\text{nc}}; \mathbf{X}) = V^{\text{conservation}} - V^{\text{nonconservation}}$.

$Y_2 = 1$ if $Y_2^* > 0$ (adopt any one of the conservation practices), and $Y_2 = 0$ otherwise (not willing to adopt any conservation practice). $V^{\text{nonconservation}}$ stands for that from not adopting conservation practices, and υ_2 is the disturbance term in Equation 4.

Chapter IV: Empirical Results and Discussion

The conservation agriculture (CA) bundles were numbered 1-8. Table 4-1 explains the bundle make-up and results. The Precision Agriculture Technology (PAT) bundles were also numbered 1-8. Table 4-2 explains the bundle make-up and results. The practice bundles were regressed against seven farmer characteristics: highly productive land (HPL), cropland acres, CSP, age, education score, off-farm income, and a cattle operation, plus a constant.

Conservation Bundles Marginal Effects

Table 4-1. Multinomial Logit Marginal Effect Results for Conservation Bundles

Conservation Practice Adoption Bundle	Highly Productive Land (HPL)	Cropland Farm Size	Off farm Employment	Age	Education	Cattle Operation	Conservation Stewardship Program (CSP)
1 No Conservation Practice	0.2641 *** (0.0857)	0.0000 ** (0.0000)	0.1058 (0.1003)	0.0055 * (0.0033)	0.0114 (0.0289)	-0.2272 *** (0.0849)	0.0899 (0.1010)
2 Cover Crops (CC)	0.0126 (0.0283)	0.0000 (0.0000)	0.0190 (0.0168)	0.0004 (0.0009)	0.0118 * (0.0071)	0.0513 ** (0.0242)	0.0220 (0.0223)
3 No-Till/Strip-Till (NTST)	-0.0816 (0.0827)	0.0000 (0.0000)	0.1327 (0.0943)	-0.0048 (0.0031)	-0.0310 (0.0286)	0.0895 (0.0775)	0.0096 (0.0988)
4 Diverse Crop Rotation (DCR)	0.0031 (0.0020)	0.0000 (0.0000)	-0.0602 *** (0.0231)	0.0000 (0.0001)	-0.0014 * (0.0008)	0.0037 (0.0023)	0.0004 (0.0023)
5 CC & DCR	-0.0212 (0.0462)	0.0000 (0.0000)	-0.0620 (0.0629)	0.0000 (0.0018)	-0.0073 (0.0179)	0.0290 (0.0367)	-0.0597 (0.0602)
6 CC & NTST	0.0241 (0.0656)	0.0000 (0.0000)	-0.1476 (0.0924)	-0.0049 ** (0.0025)	0.0241 (0.0256)	0.0272 (0.0642)	-0.0713 (0.0797)
7 DCR & NTST	-0.1894 *** (0.0705)	0.0000 (0.0000)	0.0134 (0.0822)	0.0039 * (0.0022)	-0.0079 (0.0232)	0.0258 (0.0697)	0.0093 (0.0837)
8 CC, DCR, & NTST	-0.0118 *** (0.0029)	0.0000 (0.0000)	-0.0011 (0.0006)	0.0000 (0.0000)	0.0002 (0.0002)	0.0007 * (0.0004)	-0.0001 (0.0005)

Significance Level: *** =.01, ** = .05, * = 0.1

Results from the conservation bundles revealed several significant results. The most significant result was the relationship between HQL and CA practices. CA practice adoption bundle 1, no adoption, resulted in a significant positive coefficient, while bundles 7 (TCR & NTST) and 8 (All three) had negative coefficients. This could be attributed to the soil type of HQL. This type of land is typically comprised of heavier soils that farmers tend to be more comfortable farming with conventional tillage practices. Also, HQL tends to attract higher grossing crops such as corn and soybeans. Another significant result was the negative coefficient with off farm employment and TRC. For the farmer with off farm employment, a rotation of more than two crops adds greater complexity which was expected to negatively affect adoption (Lichtenberg, 2001 and Gedikoglu, 2007).

Another significant finding was the negative coefficient associated with having cattle and no adoption. This can be interpreted a few different ways. One possibility is having cattle results in having marginal or highly erodible land. 89.2% of the farmers that had cattle reported having a cow-calf operation. Pasture is a typical a requirement for most cow-calf operators. Management of this land directly effects the long-term viability and productivity of the land, so farmers are more aware of the consequences. Another possibility is conservation practices may be a requirement to mitigate the externalities of having cattle. Having cattle also increased the likelihood the adoption of CC. This was not surprising, according to our survey 64.5% of CC adopters grazed the cover crops.

One surprising result was farm size having a virtually neutral effect on conservation adoption. An argument could be made both ways for these CA practices to be more likely on either large or small farms. One could theorize that a small farm would be more willing to adopt conservation to conserve the smaller number of acres farmed and implantation would be easier. Likewise, for larger farms, one could theorize that size would bring more opportunities and resources for CA implementation. However, similar results were observed by Gong and Bergtold (2013), with total acres having a virtually neutral marginal effect on the unconditional and conditional adoption of no-till, cover crops, and use of manure. The unconditional results for cover crops and no-till were both significant at a minimum of .10.

Precision Bundles Marginal Effects

Table 4-2. Multinomial Logit Marginal Effect Results for Precision Bundles

Precision Agricultural Technology (PAT) Practice Adoption Bundle	Highly Productive Land (HPL)	Cropland Farm Size	Off farm Employment	Age	Education	Cattle Operation	Conservation Stewardship Program (CSP)
1 No PAT Practice	0.05956	0.00002	0.00611 **	0.11242	0.02052	0.02520	-0.02661
	(0.0629)	(0.0000)	(0.0027)	(0.0787)	(0.0226)	(0.0654)	(0.0769)
2 Variable Rate Technologies	0.01985	0.00000	0.00016	0.01581	0.00164	-0.01098	0.01441
	(0.0280)	(0.0000)	(0.0012)	(0.0425)	(0.0098)	(0.0379)	(0.0310)
3 Yield Monitor (YM)	-0.00092	0.00000	-0.00003	0.00017	-0.00012	0.00028	-0.01890 **
	(0.0013)	(0.0000)	(0.0000)	(0.0016)	(0.0005)	(0.0010)	(0.0085)
4 GPS	-0.06918 *	-0.00002	0.00070	0.07597 **	-0.00263	0.06925 *	-0.03516
	(0.0401)	(0.0000)	(0.0014)	(0.0353)	(0.0083)	(0.0391)	(0.0504)
5 VRT & YM	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
6 VRT & GPS	0.00000	0.00000	0.00000	0.00002	-0.00001	0.00045 *	0.00005 ***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0003)	(0.0000)
7 YM & GPS	-0.12451 *	-0.00002	0.00137	-0.02837	-0.00050	0.12918 *	0.18518 **
	(0.0730)	(0.0000)	(0.0025)	(0.0934)	(0.0269)	(0.0764)	(0.0809)
8 VRT, YM, GPS	0.11521	0.00002	-0.00832 ***	-0.17602 *	-0.01890	-0.21337 **	-0.11897
	(0.0845)	(0.0000)	(0.0032)	(0.1000)	(0.0305)	(0.0840)	(0.0996)

Significance Level: *** =.01, ** = .05, * = 0.1

There were three notable results from this analysis. The first was off farm employment resulted in a significant positive coefficient with PAT bundle 1 (no adoption) and a negative coefficient for PAT bundle 8 (all adoption). Like the results from the CA bundle, greater complexity may be a deterrent of adoption. The second finding was CSP adoption became significant, with both PAT bundles 6 and 7 having positive coefficients. Given that certain CSP enhancements focus adoption of PAT, this suggests the program is having an influence on adoption rates in South Dakota. The third was the positive and negative coefficients associated with cattle operations. Although two PAT bundles had positive coefficients at the 10% level, in PAT bundle 4 and 7, there was a larger negative coefficient at the 5% level. This was a surprising result that will warrant further analysis. It appears cattle operations may adopt some of the PATs, but they are less likely to adopt all PATs. Four bundles, 2, 3, 5, and 6, all had less than 10 responses. The results are still shown in table 4-2, however because of the limited responses, omitted as meaningful.

Bivariate Probit Results

Table 4-3. Bivariate Results of CA and PAT Bundles

Farmer Characteristic/ Adoption	Highly Productive Land (HPL)	Cropland Farm Size	Conservation Stewardship Program (CSP)	Age	Education	Off farm Employment	Cattle Operation	Constant	Adoption rate (%)	rho
Conservation Adoption	-0.6946 ***	-0.0001	-0.2227	-0.0128	-0.0431	-0.3484	0.6989 ***	1.7204	72%	0.2840 ***
	(0.2165)	(0.0000)	(0.2522)	(0.0082)	(0.0740)	(0.2514)	(0.2174)	(0.6205)		(0.1334)
Precision Agriculture Technology	0.1098	0.0000	0.2645	-0.0224 **	-0.0541	-0.6542 ***	-0.3000	2.4624	75%	
	(0.2139)	(0.0000)	(0.2602)	(0.0088)	(0.0754)	(0.2502)	(0.2098)	(0.6785)		

Significance Level: *** =.01, ** = .05, * = 0.1

Results in Table 4-3 supported the hypothesis that CA and PAT were positively correlated. One of the most significant results was HPL had a negative effect on CA. As discussed earlier, because farmers in HPL areas are more likely to plant corn and soybeans and their land is inherently more adaptable to conventional tillage, it's not surprising to see this result. Other results from conservation adoption show an almost inverse result with the presence of a cattle operation compared to HPL. As discussed earlier, farmers with cattle may be more conservation minded for various reasons. As for PAT, we saw significant results for age and off-farm employment. Both have negative coefficients. From the statistical analysis, it was suggested that these two factors may negatively impact adoption and they did. Adoption rates of any of the practices were similar, 72% for CA and 75% for PAT.

Two surprises were cropland having a negative, although not significant, sign associated with its coefficient. During the statistical analysis, it appeared farm size, both overall and total cropland acres, would both have a positive effect on adoption of both CA and PAT practices. However, consistently there was no effect. Theoretically, it could be postulated with the variance in farming operations based on location in South Dakota, that farms in the HPL region required less acres than farmers in the rest of the state. For example, a farm with 1,000 acres in the HPL may be profitable enough to justify PAT adoption, but a farmer from the rest of the state could not justify PAT adoption farming the same 1,000 acres. Another surprising result was the coefficients for CSP, although not significant, was negative for CA and positive for PAT. This enforces the notion that was observed in the multinomial logit results that CSP had a positive effect on PAT adoption, and none on CA adoption practices.

Chapter V: Farmers' Preferences for Conservation Practices and Precision Technologies

With limitations on the amount and depth of personal financial information survey participants are typically willing to disclose, collecting accurate economic data about specific practices can be difficult and non-representative. Aggregate financial data of South Dakota farms is limited, with only 74 farms participating in the South Dakota Center for Farm and Ranch Management record system (Mitchell Technical, 2018). As a proxy for a farmer's perception of the practices, a set of Likert-style scales was created to capture a farmer attitude towards certain practices and questions related to those practices. Using these Likert-style scales allowed for the collection of data that was more easily obtained and less invasive to a farmer's privacy. A uniform scale was created and used throughout the survey to help create continuity and limit confusion on what was being asked on each scale. The farmers were asked to score the importance of various reasons influencing their adoption and non-adoption decisions as follows: (1) Not Important, (2) Slightly Important, (3) Moderately Important, and (4) Very Important. Although each practice had a different statements and reasons for each scale, there were groups of similar base questions that appeared throughout the survey. These groups focused on profitability, productivity, environmental conservation and concerns, and the influence of federal programs.

Likert-style scales were created for 5 of the 6 practices used in the multinomial logit and bivariate probit analysis. They include no-till, cover crops, and PATs. PATs are consolidated into one group, lumping all PAT practices into one group. In hindsight, collecting standardized individual practice data on YM, VRT, and GPS in a similar form to both no-till and cover crop adoption would have strengthened the analysis, allowing another point of reference to cross check the other data collected on the practices

Precision Agriculture Technology Adoption and Non-adoption

Two Likert-style scales were created to capture the farmer's perceptions and reasons for both adoption and non-adoption of PAT. The survey question for PAT adopters was worded "If you answered "Yes" to any precision technology questions above, indicate the importance of each of the following in your adoption decision?" This resulted in responses from any respondent who used at least one of the PATs asked about in the survey. For non-adopters, there were responses from those who used some or none of the PATs listed in the survey. Additionally, to follow the theme of the previous regression analyses, the responses to these question from NTST, cover crops, and a diverse crop rotation adopters and non-adopters was also evaluated to look for any distinguishable trends in rankings and raw scores.

The Table 5-1 focuses on the reasons of adoption for PAT users. The highest ranked reasons for adoption were increased productivity and better use of inputs (3.71), which were tied for the first, while increase in profits (3.66) was third, environmental benefits (3.23) was fourth, and helps manage production and price risk (3.16) was fifth. All of these ranked high, somewhere between very important (4.00) and moderately important (3.00). The remaining three fell well below these scores, with being on the forefront of technology (2.56) being sixth, the purchase of new farm equipment (2.49) ranking, and participation in federal or state program (1.78) ranking lowest at eighth.

The rankings stayed consistent across all PAT adoptions with no major score changes. One interesting observation was that the raw scores dropped for each of the top four reasons for those who didn't adopt those particular PATs versus those who did adopt.

Table 5-1. Farmer Reasons for PAT Adoption (Overall and Precision Practices)

	Overall		GPS Adoption				YM Adoption				VRT Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Better use of inputs	3.7143	1	3.7310	2	3.5000	2	3.7328	1	3.5714	2	3.8022	1	3.5738	2
Increase in profits	3.6645	3	3.6713	3	3.6000	1	3.6947	3	3.4211	3	3.7444	3	3.5333	3
Increase in productivity	3.7143	1	3.7379	1	3.4000	4	3.7252	2	3.6190	1	3.7473	2	3.6557	1
Environmental benefits	3.2267	4	3.2128	4	3.5000	2	3.2188	4	3.2000	4	3.4333	4	2.8793	5
Being at the forefront of technology	2.5592	6	2.6014	6	2.1000	8	2.6000	6	2.1500	6	2.6778	6	2.3333	7
Participating in federal or state program	1.7752	8	1.7570	8	2.1250	7	1.7283	8	2.0500	8	1.8448	8	1.6667	8
Purchase of new farm equipment	2.4900	7	2.4930	7	2.2500	6	2.5508	7	2.1000	7	2.4888	7	2.4915	6
Helps to manage production or price risks	3.1589	5	3.1678	5	3.1111	5	3.1395	5	3.2000	4	3.2198	5	3.0345	4

Source: Author's Survey

More variation was observed in Table 5-2 from the responses from non-adopters of PATs. The high cost of equipment ranked first overall (3.17) and across all PAT adoption categories and was the only reason in this table to have an overall score of greater than 3. Not profitable (2.83) and complex technology (2.82) score very close for second and third, while uncertain profits (2.74) is fourth and satisfied with current practices (2.71) was fifth. The last four were risky investment (2.65), uncertain about the environmental benefits (2.32), lack of information (2.29) and federal programs are unattractive (2.05). The order of this ranking is telling, with reasons involving cost ranking high, along with two more personal opinions (complex technology and satisfied with current practices). The reasons ranking low focus more on dissemination of facts. For example, the reason “risky investment” ranked lower than “high cost of equipment”. Both are financial considerations, but one deals with capital outlay and the other with return on investment. This infers that the respondents felt more strongly that the costs were too high rather than the technology not being profitable. It also shows that information about the benefits (uncertain about the environmental benefits and lack of information) are available, reducing the information gap experienced in some technology adoption. The farmers are aware about the new technologies and it bares less on their decision making. Again, federal programs rank very low for farmer decision making.

Scores stayed fairly similar across adoption patterns of each technology. One observed difference was the ranking changes for not profitable and satisfied with current practices. For not profitable, the rank changed from second to sixth, sixth, and fourth for those who did not adopt a certain PAT. The largest difference was between GPS and YM adopters and non-adopters. The scores were both over 0.50 points apart. It appears that those who adopted GPS and YM felt continued adoption of other PATs was not as profitable as the technologies they adopted. For those non-adopters of GPS and YM, they scored not profitable lower, while ranking the first reason, high cost of equipment, higher than GPS and YM adopters. This follows a similar pattern described by Schimmelpfenning (2016), were farms adopt technologies in steps based on return on investment. The other change was “satisfied with current practices.” In the overall rankings, it ranked fifth, however for non-adopters, it moved up in ranking to second, third, and second. This revealed that non-adopters ranked not changing their operation very high. From the survey data, the average age of a farmer that has not adopted YM and GPS were 61.8 years and adopters were 58.4 and 58.7 years, respectively. Non-adoption could be due to increased age of the farmer, which limits his incentive to invest in a technology they felt will not resulting in a positive payback over the duration of the farming career. Also, from the survey, the non-adopters farmed less cropland, roughly half of PAT adopters.

Table 5-2. Farmer Reasons for PAT Non-Adoption (Overall and Precision Practices)

	Overall		GPS Adoption				YM Adoption				VRT Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Not profitable	2.8265	2	3.0000	2	2.3600	6	3.0169	2	2.5000	6	2.9231	2	2.7414	4
Uncertain profits	2.7449	4	2.8784	3	2.5000	4	2.8475	4	2.5526	5	2.8462	4	2.7018	6
Complex technology	2.8182	3	2.8667	4	2.8333	3	2.7167	3	2.9474	2	2.7250	3	2.9123	3
High costs of equipment	3.1748	1	3.1711	1	3.3333	1	3.0968	1	3.2750	1	3.0000	1	3.3333	1
Risky investment	2.6495	6	2.7162	5	2.5000	4	2.5932	6	2.7027	4	2.5128	6	2.7193	5
Uncertain about environmental benefits	2.3232	7	2.4267	7	2.1667	8	2.3333	7	2.2632	8	2.4500	7	2.2456	8
Lack of information	2.2887	8	2.3784	8	2.1739	7	2.2712	8	2.2703	7	2.3077	8	2.2857	7
Federal programs are unattractive	2.0510	9	2.1067	9	2.0435	9	1.9322	9	2.1842	9	1.8718	9	2.1754	9
Satisfied with the current practice	2.7129	5	2.6494	6	2.8400	2	2.6066	5	2.9231	3	2.4634	5	2.9153	2

Source: Author's Survey

Beyond whether the farmer adopted a PAT practice or not, the adoption choice of PAT practices in relation to CA practices was also evaluated. The three CA practice evaluated were the same as in the regression analysis, cover crops, diverse crop rotation, and NTST. A similar evaluation was done and two tables (Table 5-3 and Table 5-4) were created to show changes in rankings and score for each CA practice.

For those who did adopt PAT practices, there were no significant observed changes in rankings and the scores were similar. There was some variation between rankings of the top three reasons, increased profits, better use of inputs, and increased productivity, but the difference in raw scores was small. There was some variation in the raw scores from the overall averages for cover crop adoption. Cover crop adoption had the widest range of scores between adopters and non-adopters. The widest range was observed for the reason participating in a federal or state program. Adopters of cover crops gave a lower raw score (1.71) to this reason than those who were non-adopters of PAT practices (2.05), with the overall score at 1.78. This observation implies that those who used both PAT practices and cover crops were less concerned about government programs than those who only adopt PAT practices, and those who don't use cover crops put a higher emphasis on federal funding. This is an interesting observation, but both are still the lowest rankings of their subset.

Table 5-3. Farmer Reasons for PAT Adoption- Overall and by CA Practice (Overall and Conservation Practices)

	Overall		NTST Adoption				Cover Crop Adoption				Crop Rotation Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Better use of inputs	3.7143	1	3.8041	1	3.5614	2	3.7358	3	3.5714	2	3.7857	1	3.6735	2
Increase in profits	3.6645	3	3.7010	3	3.6000	3	3.7547	2	3.4211	3	3.7273	3	3.6289	3
Increase in productivity	3.7143	1	3.7677	2	3.6182	1	3.8148	1	3.6190	1	3.7679	2	3.6837	1
Environmental benefits	3.2267	4	3.3021	4	3.0926	4	3.4038	4	3.2000	4	3.2075	4	3.2371	4
Being at the forefront of technology	2.5592	6	2.5979	6	2.4909	6	2.6038	6	2.1500	6	2.5556	6	2.5612	6
Participating in federal or state program	1.7752	8	1.7526	8	1.8148	8	1.7130	8	2.0500	8	1.7264	8	1.8021	8
Purchase of new farm equipment	2.4900	7	2.5105	7	2.4545	7	2.3796	7	2.1000	7	2.5189	7	2.4742	7
Helps to manage production or price risks	3.1589	5	3.2500	5	3.0000	5	3.2075	5	3.2000	4	3.1481	5	3.1649	5

Source: Author's Survey

Rankings for PAT non-adopters of each of the CA practices was also very similar to the overall rankings. However, the scores tended to shift up or down depending on the CA practice. PAT non-adopters that were NTST adopters scored all reasons, besides being satisfied with current practices, higher than those who did not adopt NTST. In short, NTST adopters felt more strongly for reason of not adopting PAT practices than those who were NTST farmers. NTST was also the only CA practice that had a change in the rankings. The overall ranking for non-adopters for the reason satisfied with current practices was fifth with a score of 2.71. For those who were also NTST adopters, the ranking was sixth and the score was 2.57. However, for non-adopters of both practices, being satisfied with current practices moved to second and the raw score went up, 2.85, where the rest of the score went down. These results imply two thoughts on rationale. The first, PAT non-adopters who are NTST adopters, scored their reason higher except for satisfied with their current practices, alluding that they are less satisfied than others about their current practices, which means they could be an excellent candidate for PAT incentive programs. The second is that PAT and NTST non-adopters rank “satisfied with current practices very high and would not be good candidates for a targeted program. From the survey data, the average age of a non-adopter of NTST was older than adopters with less cropland acres.

Table 5-4. Farmer Reasons for PAT Non-Adoption- Overall and by CA Practice (Overall and Conservation Practices)

	Overall		NTST Adoption				Cover Crop Adoption				Crop Rotation Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Not profitable	2.8265	2	3.0426	2	2.6275	4	2.7586	4	2.8551	2	2.9355	2	2.7761	2
Uncertain profits	2.7449	4	2.8750	4	2.6200	5	2.7241	5	2.7536	4	2.8750	4	2.6818	5
Complex technology	2.8182	3	3.0000	3	2.6471	3	2.8276	2	2.8143	3	2.9063	3	2.7761	2
High costs of equipment	3.1748	1	3.2000	1	3.1509	1	3.0645	1	3.2222	1	3.2500	1	3.1408	1
Risky investment	2.6495	6	2.7234	5	2.5800	6	2.7241	5	2.6176	6	2.8065	5	2.5758	6
Uncertain about environmental benefits	2.3232	7	2.3878	8	2.2600	7	2.3000	7	2.3333	8	2.5152	7	2.2273	8
Lack of information	2.2887	8	2.4468	7	2.1400	8	2.0345	8	2.3971	7	2.3226	9	2.2727	7
Federal programs are unattractive	2.0510	9	2.1064	9	2.0000	9	2.0000	9	2.0725	9	2.4194	8	1.8806	9
Satisfied with the current practice	2.7129	5	2.5714	6	2.8462	2	2.8000	3	2.6761	5	2.6364	6	2.7500	4

Source: Author's Survey

No-till and Strip-till Adoption and Perceptions

In the survey, farmers were also asked to score the reasons why they either adopted, quit, or never adopted no-till or strip till practices in their farm. Most of the farmers identified as either adopters and non-adopters of NTST. There were 36 farmers who identified as NTST adopters who quit using NTST. Table 5-5 shows the raw scores and the ranking of each reason listed. Lower yields, satisfied with the current practices, and not profitable ranked first, second and third, respectively. Like the other survey adoption reasons, a low emphasis was placed on federal programs. Federal programs were unattractive and placed last again, with a much lower score than most other reasons.

Table 5-5: Farmer Reasons for the Disadoption of No-till and Strip-till

Reason	Score	Rank	Reason	Score	Rank
Lower yields	3.22	1	No improvements in water availability	2.66	5
Satisfied with the current practices	3.14	2	No improvements in soil quality	2.66	5
Not profitable	2.97	3	Time constraints	2.42	7
High cost of equipment	2.68	4	Federal programs were unattractive	2.22	8

Source: Author's Survey

For NTST adopters, they had very strong scores for their top five self-reported reasons for adopting NTST. Improves water availability and conservation (3.83) ranked first, with the highest raw score of any of the overall rankings. Improves soil quality (3.79), increased farm productivity (3.72) and increases farm profitability (3.70) were all close with a second, a third, and, a fourth ranking. Participation in a federal program had the lowest raw score (1.59) of any of the overall scores and ranked eighth. Scores and rankings stayed consistent across all categories of PAT practices. NTST adopters seemed to have the strongest feelings towards the reason for adoption of the practices that actually benefited their operation because of the practice itself and scored poorly federal programs as a reason for using the practice. Farmers are adopting NTST more because it improves their operation and less because of government incentives to use the practice.

Table 5-6. Farmer Reasons for NTST Adoption- Overall and by PAT Practice

	Overall		GPS				YM				VRT			
			Yes		No		Yes		No		Yes		No	
Practice	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
High cost of equipment	2.8203	2	2.8750	3	2.8889	1	2.8171	3	2.9667	2	2.8393	3	2.9070	2
Uncertain about environmental benefit	2.3684	4	2.4103	5	2.5200	4	2.4474	5	2.4615	4	2.5185	5	2.4054	5
Not profitable	2.7719	3	2.9474	2	2.6154	3	2.9730	2	2.5926	3	3.0800	1	2.6410	3
Time constraints	2.3966	5	2.5128	5	2.4231	5	2.5135	4	2.4286	5	2.5200	4	2.4500	4
Lack of information	2.0179	6	2.0811	6	1.9615	7	2.1389	6	1.8889	7	2.0800	6	2.0000	7
Satisfied with the current practices	3.0938	1	3.1591	1	2.8889	1	3.0952	1	3.0000	1	2.8621	2	3.1905	1
Federal programs are unattractive	2.0000	7	1.9750	7	2.1923	6	1.9730	7	2.1724	6	1.9600	7	2.1220	6

Source: Author's Survey

For non-adopters of NTST, satisfied with current practices (3.09) scored and ranked highest overall and across all PAT adoption categories. High cost of equipment (2.82) and not profitable (2.77) ranked second and third, respectively. For the lowest scored and ranked reasons, lack of information (2.02) and federal programs are unattractive (2.02) had similar raw scores and ranked sixth and seventh. There were no significant observed differences in any of the raw scores and rankings across all PAT adoption decision categories. These perceptions or reasons for non-adoption imply two thoughts on rationale of these farmers. The first is again a link between costs and being satisfied with current practices. Similar to PAT non-adopters, NTST non-adopters tended to be older (60.5 versus 58.7 years) and farmed less cropland (2,296.6 versus 1,416.5 acres). Their smaller number of acres and age could contribute to them scoring “high cost of equipment” and “not profitable” high as well. They may feel their age and farm size would limit the potential return on the equipment needed to switch over and they have decided against the change. The second thought pertained to the lower ranked reasons, “participation in a federal program” and “lack of information”. These two reasons are very telling and complement the first thought. Because NTST non-adopters scored the first three reasons the highest, and the last to lowest, it shows the farmer may be aware of the benefits and government programs to incentivize increased adoption but has little bearing on their adoption decision. As Caneles et al (2014) showed, an increase in payments can improve adoption rates, however payment amounts can increase significantly, and the farmer would still not adopt the practice. More information probably would not have much of an effect on increased adoption rates either. Farmers may be aware of the benefits, but choose not to adopt because of the individual characteristics of their farm.

Table 5-7. Farmer Reasons for NTST Non-Adoption- Overall and by PAT Practice

	Overall		GPS				YM				VRT			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Improves soil quality	3.7885	2	3.7789	2	3.7692	2	3.7711	2	3.7727	3	3.8033	1	3.7273	4
Improves water availability/water co	3.8269	1	3.8105	1	3.8462	1	3.7952	1	3.8636	1	3.7705	2	3.8636	1
Environmental stewardship	3.5631	5	3.6667	5	3.2308	5	3.6173	5	3.5455	5	3.6667	3	3.5116	6
Adaptation to climate change	2.6078	7	2.6064	6	2.9167	6	2.4878	7	3.0476	7	2.5085	7	2.7273	4
Increases farm productivity	3.7184	3	3.6915	3	3.7692	2	3.6585	4	3.8182	2	3.6333	4	3.7727	2
Increases farm profitability	3.7019	4	3.6842	4	3.7692	2	3.6627	3	3.7727	3	3.6393	4	3.7500	3
Inadequate labor supply	2.8922	6	2.9789	7	2.3636	7	2.8072	6	3.2000	6	2.8333	6	2.9535	7
Participation in federal programs	1.5978	8	1.5952	8	1.9091	8	1.5600	8	1.9474	8	1.6852	8	1.5750	8

Source: Author's Survey

Cover Crops Adoption and Farmer's Perceptions

The survey also asked questions about the adoption rates and reasons for using cover crops on the farmers' operation. Of the survey respondents, 62 farmers claimed use of cover crops over some of their operation in 2016. The acres of use were not collected, rather if the farmer used any cover crops in 2016. Of the nearly two hundred survey respondents, mostly from the eastern half of South Dakota, 51% raised cattle in some form, either beef or dairy. Of those livestock farmers, 94% grazed crop residue, however only 39% grazed cover crops. Additionally, of the total respondents, 31.3% used cover crops in their operation in 2016, with 64.5% of them using cover crops with livestock integration. (Kolady and Deutz, 2017)

Table 5-8. Farmer Reasons for CC Adoption- Overall and by PAT Practice (Overall and Precision Practices)

	Overall		GPS Adoption				YM Adoption				VRT Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Improves Soil Health	3.6200	1	3.6600	1	3.4200	2	3.6800	1	3.4500	1	3.7400	1	3.4200	1
Prevents Soil Erosion	3.0300	5	3.0800	5	2.8200	5	3.0900	5	2.8400	6	3.1300	5	2.8400	6
Suppresses Weeds	2.8600	6	2.9600	6	2.3600	8	2.9600	6	2.6300	7	2.8900	6	2.8100	7
Breaks Pest and Disease Cycles	2.8300	7	2.8900	7	2.5500	6	2.8600	7	2.7400	8	2.8700	7	2.7600	8
Improves Soil and Water Availability	3.4800	3	3.5000	3	3.4200	2	3.5100	3	3.4000	2	3.6600	2	3.2200	3
Increases Farm Prodcutivity	3.5400	2	3.5500	2	3.5000	1	3.5900	2	3.4000	2	3.6300	3	3.3800	2
Increases Farm Profitability	3.2300	4	3.2600	4	3.0800	4	3.3200	4	3.0000	4	3.2900	4	3.1200	4
Helps with Livestock Intreration	2.7700	8	2.8400	8	2.5000	7	2.6600	8	2.9500	5	2.6300	8	2.9200	5
Participation in Federal Programs	1.9800	9	2.0800	9	1.5500	9	1.9400	9	1.9400	9	2.0000	9	1.8800	9

Source: Author's Survey

Table 5-8 gives the aggregate scores and ranking for the overall survey population, PAT adopters and non-adopters by category. For adopters of cover crops, the overall reasons for adoption were: improves soil health (3.62), increases farm productivity (3.54), and improves soil water availability and water conservation (3.48). The next five ranked reasons also scored moderately high: increases farm profitability (3.23), prevents soil erosion (3.03), suppresses weeds (2.86), breaks pest and disease cycle (2.83), and helps with livestock integration (2.77). As with the other reasons listed, participation in a federal program was last, with a raw score of 1.98. Rankings stay consistent across all PAT adopters and non-adopters for the most part, with only slight changes in some closely scored reasons for adoption. One observation was the raw scores tended to be higher for adopters of PAT practices versus those who did not adopt PAT practice, except in two instances. Non-adopters of YM and VRT scored and ranked “helps with livestock integration” higher than adopters. From the multinomial logit regression, there was a significant negative marginal effect for having all three PATs if the farmer also had cattle and a positive marginal effect for having cover crops, both significant at 0.05% level. These findings help explain this reversal in the farmers reasons for adoption.

In a further focus on cover crops and livestock integration, Kolady and Deutz, 2017, explored the relationship between cover crop adopters who were and were not livestock integrators. "Data presented in (Table 5-9) shows that "Improves soil health", "Increases farm productivity", and "Improves water availability/water conservation" scored high among adopters." One interesting finding was that "Helps with livestock integration" was relatively lower on the list for all cover crop adopters. However, as we stated before, only 64.5% of cover crop adopters used them with livestock integration, primarily because they don't have livestock. By separating out the segment of farmers without livestock, the difference in adoption reasons between the aggregate of cover crop farmers (Table 5-9) and those using with livestock emerges (Table 5-10).

Table 5-9. Farmer Reasons for CC Adoption- Overall

Ranking	Reasons For Using Cover Crops	Score
1	Improves soil health	3.62
2	Increases farm productivity	3.54
3	Improves soil water availability/ water conservat	3.48
4	Prevent soil erosion	3.03
5	Suppress weeds	2.86
6	Breaks pest and disease cycle	2.83
7	Helps with livestock integration	2.77
8	Increases farm profitability	2.15
9	Participation in federal programs	1.98

Source: Kolady and Deutz, 2017

Table 5-10. Farmer Reasons for CC Adoption- Livestock

Ranking	Reasons For Using Cover Crops	Score
1	Improves soil health	3.59
2	Increases farm productivity	3.59
3	Improves soil water availability/ water conservat	3.56
4	Increases farm profitability	3.28
5	Helps with livestock integration	3.26
6	Prevent soil erosion	3.03
7	Breaks pest and disease cycle	2.95
8	Suppress weeds	2.8
9	Participation in federal programs	1.74

Source: Kolady and Deutz, 2017

There are a few noticeable changes in the rankings when adopters of cover crops are separated into those with or without livestock. The first increased raw score and ranking for increases farm profitability and helps with livestock integration. The increased raw score and ranking for “Helps with livestock integration” may be inherent, with the obvious connection of sorting those with livestock and those without. However, “Increases farm profitability” is more exogenous, with profitability rising from the based on having livestock or not, implying profitability was directly affected by livestock and not cover crops. This metric increased from a ranking of eighth place to fourth place, with an increase in the raw score of 52%, 2.15 to 3.28. This was the largest score change among all of the comparisons of the Likert scales. There is no financial data available for these farms to substantiate this claim, however with the increase in the raw score of “Helps with livestock integration”, there is a link between the two adoption reasons.

There was also a decrease in the raw score for “Participation in a federal program”. Although the score and rank were the lowest of all the reasons, it did drop from the overall score of 1.98 to 1.76 for with cattle farmers. This is important in that it implies livestock farmers need less of an incentive to use cover crops than the overall population of adopters. If this is true, then policies that promote more the use of cover crops and livestock or slight increase in subsidy incentives could improve the overall adoption rate of the practice.

For non-adopters of cover crops, the top two reasons for non-adoption were “Planting time conflicts with harvest of a cash crop” (3.07) and “Satisfied with current practices” (2.86). Looking at the TCR rates of cover crop adopters and non-adopters in the survey, 56% of adopters had a TCR while only 29% of TCR non-adopters had one. This less diverse rotation lead to a higher percentage of corn and soybean acres. Because of the difficulties establishing cover crops with these two crops, this aligns with the responses from the survey. A more diverse crop rotation that includes small grains presents a better window for the establishment of small grains, with a longer growing season and a better chance of precipitation. As for “Satisfied with current practices”, according to the survey non-adopters tended to be older, farm less acres, own less overall land, and had nearly four times as much pasture land.

The rest of the reasons for non-adoption raw scores and rankings stayed consistent across all PAT practices and adoption choices. One interesting observation was for “Uncertain about the environmental benefits” had the widest variations between PAT adopters and non-adopters and the most significant rank changes. Raw scores for PAT non-adopters dropped between 0.5 and 0.24. On possibility for this discrepancy could be a knowledge gap between the two. As with other adoption questions, government role played a small role in the decision.

Table 5-11. Farmer Reasons for CC Non-Adoption- Overall and by PAT Practice (Overall and Precision Practices)

	Overall		GPS Adoption				YM Adoption				VRT Adoption			
			Yes		No		Yes		No		Yes		No	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Not profitable	2.3700	4	2.4300	4	2.1200	4	2.4900	3	2.1000	5	2.3700	5	2.3900	3
Planting Time Conflicts with Harvest of Cash Crop	3.0700	1	3.1500	1	2.8600	1	3.1600	1	2.8300	1	3.0400	1	3.0800	1
Uncertain about the Environmental Benefits	2.2500	5	2.3800	5	1.8800	7	2.3000	6	2.0600	6	2.4000	4	2.0700	7
Uncertain about Yield Benefits	2.4000	3	2.5100	3	2.1200	4	2.4700	4	2.1700	4	2.4700	3	2.3100	4
Risky investment	2.2000	6	2.2500	6	2.0000	6	2.3400	5	1.9000	7	2.1200	6	2.3000	5
Federal Programs are unattractive	2.1500	7	2.1500	7	2.1900	3	2.1000	7	2.1900	3	2.0600	7	2.1900	6
Satisfied with the current practice	2.8600	2	2.8500	2	2.8300	2	2.8900	2	2.8300	1	2.7200	2	3.0000	2

Source: Author's Survey

Omission of Crop Rotation Question

No Likert style scale was used in the survey for Diverse Crop Rotation. The omission of DCR was not a flaw in the survey creation, but more as a condensation of focus of where the survey led the research. The initial goal was to collect as much data on the practices as possible given limited resources. If I were going to recreate this survey for a follow-up study on the subject, more emphasis would have been put on the six practices that presented themselves as the focus of the research. However, the data that was collected is quite useful and adds another layer of context to the overall analysis. In the survey, a question was asked if the farmer practiced a crop rotation, in which 100% of the respondents said yes. Using the TCR variable (greater than 2 crops grown), only 38% had a diverse crop rotation. Because the variable was created latter, it was not possible to capture that data. Capturing detailed data would have made the analysis completer and more comprehensive.

Conclusion

Although these are only perceptions and opinions of why farmers chose to adopt or not to adopt a practice, it provides some useful insight into the mind of these farmers. One observation was that adopters tended to have higher all-around scores than non-adopters, showing an enthusiasm towards the practice they chose to use. Even when separating adopters and non-adopters by other practices, adopter and non-adopter groups, adopters still tended to have higher raw scores. For non-adopters, financial reasons usually topped the list of reasons, such as cost of equipment and the practice not being profitable. They also tended to rank being satisfied with their current practices high on the reasons for non-adoption.

Farmers also ranked government assistance lowest in nearly every category and subcategory of practices. South Dakota farmers appear to not look favorably towards government assistance. This is somewhat surprising, with nearly 31% of the farmers reporting they received some form of cost share in 2016. There could be a connection with the current political climate and the low rankings this reason consistently given. This could be an area where governmental agencies tasked with aid farmers and land owners could improve. Amore positive image could result in a higher adoption rate of practice that are positive to both the farmer and the country as a whole.

Chapter VI: Conclusion and Recommendations

The survey data collected covered a broad scope of farming operations in South Dakota. South Dakota is a large state with different farming practices throughout the state, however there were some common themes throughout the research conducted. This final chapter will review important results and make recommendations for future policy changes that may increase adoption of these practices across South Dakota farms.

A major finding was significant positive effects between CA and cattle operations and a significant negative effect between CA and HPL. From the multinomial logit results, there was a positive result and significance level at 0.01 for CA and cattle, and an almost inverse result of a negative coefficient at a significance level of 0.01 for CA and HPL. Results from our analysis show the following: 1) farmers with cattle implement CA practices as defined by this study, and 2) farmers with HPL do not use these practices. There are various reasons that may explain this result. Starting with cattle, farmers historically used cattle to capitalize on marginal land. If the land was not suitable for growing crops, cattle were placed on the land. If adjacent land is slightly less marginal, then implementing a practice such as NTST is a logical choice to improve production in a more arid landscape like most of South Dakota. This reason, along with the production of cattle feed such as hay, would also help to explain a DCR. Lastly, the positive relationship with Cattle and CC could be attributed to the DCR allowing for a longer growing season for CC, which would increase the possible amount of forage from the CC that could be feed to cattle.

With HPL, the opposites are true. Farmers may have less crops in a rotation because the highest grossing crops, corn and soybeans, grow well on their farms. From a farmer's perception, they have no need to implement these practices, because they do not fit and are not needed in their operation. This assessment is supported by the Likert scales, with the top reasons for not adopting a CC being "conflicts with a cash crop" and "satisfied with current practices", and for NTST being "satisfied with current practices." This strong sentiment among farmers is a barrier to adoption.

It was also observed that off-farm income negatively effects the more labor-intensive and possibly more capital-intensive practice of TCR. As noted by Gedikoglu et al (2007), farmers with OFE have less available time for farming, so this creates a barrier for adoption. OFE also significantly affected adoption decisions in a negative way. Again, since PATs are more labor and capital-intensive practices, it makes sense that it would have a negative effect on adoption. Although mixed, respondents with a cattle operation showed a more significant negative effect on PATs. This coincides with the statistical analysis that mostly showed PAT adopters were less likely to have cattle than non-adopters.

Lastly, CSP adoption showed a positive relationship with two PAT bundles, which suggest that CSP influenced PAT bundle adoption. CSP offers a wide variety of "enhancement" practices a farmer can choose from, including all CA and PAT, however only the PAT enhancements had significant results in the analysis. It appears that CSP has had more of an effect helping farmers adopt PAT practices, but has not influenced much of the CA practices in this study.

It appears from this work, that targeting farmers with certain characteristics should be a goal of any policy wanting to increase adoption of any of these practices. PAT adoption appears to be helped by farmers participating in CSP. If this is a federal policy goal, then programs for the continued adoptions should exist. As non-renewable resources continue to decrease, the value of farmers reducing inputs is a societal benefit. As for OFE, if policy makers would like to keep farmers with OFE, which tends to be smaller farmers, increased resources need to be allocated toward equipping or accessing these farmers to PATs.

As for CA practices, it is clear farmers with cattle adopt these practices at higher rates, while farmers with HPL do not. From our analysis, CSP played no significant role in increasing CA adoption. This brings into question if CSP is properly targeting or incentivizing these practices enough to influence adoption rates. HPL farmers strongly resisted these practices, so incentive to change would have to be high or production would need to increase greatly. However, farmers with cattle were more likely to adopt. Focusing efforts towards cattle farmers may increase adoption rates in a population that is already more receptive to the practices.

Lastly, the positive correlation revealed by the bivariate probit models between the CA and PAT supports the hypothesis that adoption of CA and PAT are related. This is a positive finding for farmers and policy makers, showing that programs that increase the adoption of CA and PAT together, such as the CSP, will positively influence adoption of the other practice. Future policies could continue to focus on merging precision and conservation to not only conserve inputs and lower costs for farmers, but also conserve natural resources and improve the long-term viability of our agricultural system.

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Appendix 1: Survey Cover Letter

Dear South Dakota Agricultural Producer, 1/27/2017

We are conducting a research study entitled "Adoption of Conservation and Precision Agriculture Technologies in South Dakota-Crop Year 2016" as part of a pilot study for the Economics Department at South Dakota State University. The purpose of the study is to have a better understanding of farmers' uses of precision and conservation agricultural techniques and how it relates to the implementation of conservation programs on agricultural land in South Dakota. Your responses to this survey will provide a better understanding of the factors influencing adoption decisions and the benefits of these technologies. Results from the study will be made public. We hope the results from this study will help farmers like you continue to make informed decisions on technology adoption, while also influencing policy discourse on this topic.

You, as a producer, are invited to participate in this study by completing the attached survey. We realize your time is valuable and have attempted to keep the requested information as brief and concise as possible. It will take approximately 10-15 minutes of your time. Your participation in this project is voluntary. You may withdraw from the study at any time without consequence. If you find any questions on the survey to be too intrusive, feel free to leave them blank. Your responses are strictly confidential. When the data and analysis are presented, you will not be linked to the data by your name, title or any other identifying item.

Please assist us in our research and return the completed survey in the enclosed envelope. Your consent is implied by the return of the completed questionnaire. Please keep this letter for your information. If you have any questions, now or later, you may contact us at the number below. Thank you very much for your time and assistance. If you have any questions regarding your rights as a research participant in this study, you may contact the SDSU Research Compliance Coordinator at 605-688-6975, SDSU.IRB@sdstate.edu. We thank you in advance for your participation in the survey and for supporting our research at SDSU.

Sincerely,

Dr. Deepthi Kolady, Assistant Professor Allen Deutz, Graduate Research Assistant

Department of Economics, SDSU Department of Economics, SDSU

Phone- 605-688-5321

This project has been approved by the SDSU Institutional Review Board, Approval No.:

IRB-1701002-EXM

Appendix 2: Adoption of Conservation and Precision Agriculture Technologies in South Dakota - Crop Year 2016

Adoption of Conservation and Precision Agriculture Technologies in South Dakota- Crop Year 2016

The questions in this survey ask for information about you and your farm operation, particularly regarding the adoption of conservation and precision agriculture technologies. Your responses to this survey will provide an understanding of the factors influencing the adoption decisions and the benefits of these technologies. Results from the study will be made public. We hope the results from this study will help producers like you continue to make informed decisions on technology adoption, while also influencing policy discourse on this topic. Your response to this survey is voluntary and confidential.

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

Sincerely,

Dr. Deepthi Kolady, Assistant Professor

Department of Economics, SDSU

Phone- 605-688-5321

Allen Deutz, Graduate Research Assistant

Department of Economics, SDSU

Part A: Farm Operation

1.In what county is the majority of the agricultural land you operate (including owned and rented) located? ____________________ county

2.How far away from your operation base is the furthest parcel of land you operate? ________miles

3.On January 1, 2016, how many acres did this operation: (**If none, mark X**)

	None	Acres
a. Own?	☐	
b. Rent or lease from others or use rent free?	☐	
c. Rent to others?	☐	

4.For the total acres operated in 2016, how many acres were: **None** **Acres**

a. Cropland (**Exclude** hay acres, land in government programs, and cropland pasture) ☐

b. Pastureland (**Include** cropland /woodland pasture, other pasture and rangeland) ☐

c. Hayland (Alfalfa or grass) . . . . ☐

d. Land in government programs (CRP or other) . . . . ☐

5. For cropland acres (Question 4a), please indicate the acres and production:

Crop	**Acres harvested, if none mark X**		**Total production**
	None	**Number of Acres**	
Corn for grain			Bu.
Corn for silage			Tons
Soybean			Bu.
Wheat			Bu.
Oats			Bu.
Barley			Bu.
Hay - Alfalfa			Tons
Hay - Other			Tons
Sunflower			lbs.
Other (specify)			

6. Did you own any cattle in 2016? Check (✓) one box per row.

Cattle type	**Own**	
Beef-Cow Calf	Yes ☐	No ☐
Beef- Feeders (Dairy or Beef)	Yes ☐	No ☐
Dairy- Cows or Replacements	Yes ☐	No ☐

Part B: Conservation Agriculture Practices

7. Do you follow a crop rotation on your farm operations? Check (✓) one. Yes ☐

No ☐

a. Please list your typical crop rotation.

____

8. Did you use cover crops in 2016? Check (✓) one. Yes ☐

No ☐

9. Did you graze crop residue and/or cover crops in 2016? Check (✓) one.

a. Crop residue? Yes ☐

No ☐

b. Cover crops? Yes ☐

No ☐

If you did not use cover crops go to Q11.

10. **If you used cover crops in 2016 or before**, please indicate the importance of each of the following reasons for adoption. (**Check ✓one box per row**).

Reason	**Not Important**	**Slightly Important**	**Moderately Important**	**Very Important**
Improves soil health				
Prevent soil erosion				
Suppress weeds				
Breaks pest and disease cycle				
Improves soil water availability/water conservation				
Increases farm productivity				
Increases farm profitability				
Helps with livestock cropland integration				
Participation in federal programs (specify name)				

11. **If you did not use cover crops in 2016**, please indicate the importance of each of the following reasons for non-adoption. (Check ✓one box per row).

Reason	**Not Important**	**Slightly Important**	**Moderately Important**	**Very Important**
Not profitable				

Planting time conflicts with harvest of cash crop				
Uncertain about the environmental benefits				
Uncertain about yield benefits				
Risky investment				
Federal program are unattractive				
Satisfied with the current practices				

12. What was your primary tillage practice for row crops in 2016?

a. No- till Yes ☐ No ☐

b. Strip-till Yes ☐ No ☐

c. Minimum/Reduced till Yes ☐ No ☐

d. Conventional till Yes ☐ No ☐

If you did not use no-till or strip till, go to Q 15.

13. **If answered Yes to no-till/strip-till in Q12**, indicate the importance of each of the following reasons for no-till/strip-till adoption. (Check ✓ one box per row).

Reason	**Not Important**	**Slightly Important**	**Moderately Important**	**Very Important**
Improves soil quality				
Improves water availability/water conservation				
Environmental stewardship				
Adaptation to climate change				
Increases farm productivity				
Increases farm profitability				
Inadequate labor supply				
Participation in federal programs (specify the name)				

14. How many years have you been using no-till/strip-till in your operation? ___________years

15. **If you did not adopt no-till/strip-till in 2016**, have you ever adopted it before? Yes ☐

No ☐

16. If you stopped using no-till/strip-till, which year did you stop using it? ____________ year

17. If you stopped using no-till/strip-till, please indicate the reasons why. (**Check ✓ one box per row**).

Reason	Not Important	Slightly Important	Moderately Important	Very Important
High cost of equipment				
Federal programs were unattractive				
No improvements in soil quality				
No improvements in water availability				
Lower yields				
Not profitable				
Time constraints				
Satisfied with the current practices				

18. If you do not use no-till/strip-till, please indicate the importance of each of the following **reasons for not adopting**. (**Check ✓ one box per row**).

Reason	Not Important	Slightly Important	Moderately Important	Very Important
High cost of equipment				
Uncertain about environmental benefits				
Not profitable				
Time constraints				
Lack of information				
Satisfied with the current practices				
Federal programs are unattractive				

19. If you currently don’t use no-till/strip-till, would you consider adoption it in future? Yes ☐

No ☐

20. Do you have/use tile drainage on any of the land you operate? Yes ☐

No ☐

21. Did you receive cost share or incentive payments in 2016 for any conservation practices implemented on your farm?

Yes ☐ No ☐

If **yes**, for which program? Check one box per row

(a) Conservation Stewardship Program (CSP) Yes ☐

No ☐

(b) Environmental Quality Incentive Program (EQIP) Yes ☐

No ☐

(c) Comprehensive Nutrient Management (CNM) Yes ☐

No ☐

(d) State programs Yes ☐

No ☐

(e) Other (Please list) ____ Yes ☐

No ☐

Part C: Precision Agriculture Technology Use

For our study, we define autosteer, variable rate, automatic section control, grid soil sampling, prescription field maps, yield monitor, crop tissue sampling, GPS guidance system, and satellite/aerial imagery as precision agriculture technologies. **If you are not using any of these technologies currently, please go to Question 30.**

22. Do you use **autosteer** on your farm operation? Yes ☐

No ☐

If yes, indicate for which of the following operations?

Operation	Year of first use	Used by (Mark ✓)			Crops used (Mark ✓)
		You	Consultant	Custom Applicator	Corn Soybean Wheat
Tillage					
Fertilizer					
Planting					
Spraying					
Harvest					

23. Do you use a **variable rate system** on your farm operation? Yes ☐

No ☐

If yes, indicate on which of the following operations?

Practice	Year of first use	Used by (Mark ✓)			Crops used (Mark ✓)
		You	Consultant	Custom Applicator	Corn Soybean Wheat
Planting					
Fertilizer-N					
Fertilizer-P					
Fertilizer-K					

24. Do you use **automatic section control/shut-offs**? Yes ☐

No ☐

If yes, indicate which of the following operations?

Practice	Year of first use	Used by (Mark ✓)			Crops used (Mark ✓)
		You	Consultant	Custom Applicator	

Planting					Corn Soybean Wheat
Spraying					
Dry Fertilizer					
Liquid Fertilizer					

25. Please indicate whether you use any of the following precision technologies on your farm.

Technology	Use Y-Yes N-No	Year of first use	Used by (Mark ✓)		
Grid soil sampling			**You**	**Consultant**	**Custom Applicator**
Prescription field maps					
Crop tissue sampling					
Yield monitor					
Aerial/satellite imagery					
GPS guidance system					

26. If you answered **Yes to any precision technology questions above**, indicate the importance of each of the following in your adoption decision? **Check ✓ one box per row.**

Reason	Not Important	Slightly Important	Moderately Important	Very Important
Better use of inputs				
Increase in profits				
Increase in productivity				
Environmental benefits				
Being at the forefront of technology				
Participating in federal or state program				
Purchase of new farm equipment				
Helps to manage production and or price risks				

27. If you use any precision technologies, how far do you need to travel to service/repair this equipment?

______________Miles

28. Do you have any service issue because of distance? Yes ☐

No ☐

29. Do you think it will be profitable for you to continue to use precision technologies in the future?

Yes ☐

No ☐

30. Please complete the following table about information sources for precision agriculture technologies even if you are not using them now or have not used before.

Use	Information source							
Mark ✓ if the source was used	Farm dealer	Crop consultant	SDSU extension	Other farmers	Other family	Trade show	News media	Gov't Agency (e.g. NRCS)

31. Please indicate the importance of the each of the following in your decision to **not adopt any of above mentioned precision technologies (Questions 22-25)**. **Check ✓ one box per row**.

Reason	**Not Important**	**Slightly Important**	**Moderately Important**	**Very Important**
Not profitable				
Uncertain profits				
Complex technology				
High costs of equipment				
Risky investment				
Uncertain about environmental benefits				
Lack of information				
Federal programs are unattractive				
Satisfied with the current practice				

32. If you **currently don't use any precision technologies**, would you adopt it in future?

Yes ☐ No ☐

33. As a crop producer you face financial risks from three primary sources: production, output price, and input cost risk. Please rank these risks 1, 2, or 3, **with 1 being a high-risk area of profitability for your farm operation, 2 being a moderate risk, and 3 being a low risk.** It is possible that you consider more than one category with the same level of risk. If so, please report it.

Risk type	**Rank**
Production risk (e.g. drought, weather change, disease/pest outbreak)	
Output price risk (e.g. low price, price fluctuations)	
Input price risk (e.g. rising fertilizer, pesticide, and seed costs)	
Fixed Costs (e.g. rents, machinery, other overhead costs)	

34. During the three-year period 2014 through 2016, indicate the frequency each of the following risk management tools were used by your crop land operation. **Check ✓one box per row.**

Risk management tools	**Never**	**Sometimes**	**Always**
Crop insurance- Yield protection			
Crop insurance- Revenue protection			
Hedging using futures to manage price risk			
Hedging using options to manage price risk			
Multi-period contracts with elevators for grain delivery			

Part D: Operator characteristics

35. What year were you born? _____________

36. Are you the primary decision maker in your operation? Yes ☐

No ☐

If yes, for how many years? __________

37. What is the annual **gross farm income** in your operation? **Please check the one that applies to you**.

1. Less than $149,999
2. $150,000 - $399,999
3. $400,000 - $749,999

4) $750,000-$1,499,999
5) $1,500,000-$2,499,999
6) $2.5 million or more

38. Do you or your spouse have any off-farm employment?

Operator Yes ☐

No ☐

Spouse Yes ☐

No ☐

39. What is your level of education? **Check ✓one that applies to you**.

1. Less than High School/GED

☐

2. High School/GED

☐

3. Some College

☐

4. Occupational/Associates Degree

☐

5. Bachelor's Degree

☐

6. Graduate/Professional Degree

☐

40. Do you use a home computer/iPad/smart phone for the following activities?

Computer	**Use**	**I-pad/Smart Phone**	**Use**
Accounting	Yes ☐ No ☐	Soil testing	Yes ☐ No ☐
Record keeping	Yes ☐ No ☐	Field scouting	Yes ☐ No ☐
Farm supplies and purchases	Yes ☐ No ☐	Rain monitoring	Yes ☐ No ☐
Obtain marketing information	Yes ☐ No ☐	Market information	Yes ☐ No ☐

Do you want a copy of the survey results mailed to you? Yes ☐ No ☐

If yes, please provide your contact information. **Thank You!**

Appendix 3: Cover Crops and Livestock Integration: An Opportunity for Profit on South Dakota Farms

Cover Crops and Livestock Integration: An Opportunity for Profit on South Dakota Farms

Allen P. Deutz, Graduate Research Assistant, Department of Economics, South Dakota State University

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Cover crops have been gaining a reemerging acceptance over the last decade, with very few producers disagreeing about the potential soil health benefits of adding a cover crops to their farming operation. However, with the low commodity prices producers are trying to reduce expenses on inputs, especially on inputs with a varying or unknown return. This leaves cover crops in a peculiar place, with a somewhat difficult to measure or an unknown monetary return from increases in soil health, fertility, and nutrient availability. This can leave some producers questioning, "How can I use cover crops and see an immediate return on my investment?" Recent research from separate departments at South Dakota State University are pointing towards one answer, livestock integration.

During Spring 2017, we conducted a farm level survey on adoption of conservation practices and precision technologies in South Dakota. Of the nearly two hundred survey respondents, mostly from the eastern half of South Dakota, 51% raised cattle in some form, either beef or dairy. Of those livestock producers, 94% grazed crop residue, however only 39% grazed cover crops. Additionally, of the total respondents, 31.3% used cover crops in their operation in 2016, with 64.5% of them using cover crops with livestock integration. The producers were asked to score the importance of several reasons influencing their cover crop adoption decisions as follows: (1) Not Important, (2) Slightly Important, (3) Moderately Important, and (4) Very Important. We also asked non-adopters to score a list of reasons why they chose not to use cover crops on their operations. The scores and rankings for each group are listed below in Table 1 and Table 2.

Table 1: Reasons for adoption of cover crops cover in South Dakota, 2016-17

Ranking	Reasons For Using Cover Crops	Score
1	Improves soil health	3.62
2	Increases farm productivity	3.54
3	Improves soil water availability/ water conservation	3.48
4	Prevent soil erosion	3.03
5	Suppress weeds	2.86
6	Breaks pest and disease cycle	2.83
7	Helps with livestock integration	2.77
8	Increases farm profitability	2.15
9	Participation in federal programs	1.98

Source: Author's Survey

Table 2: Reasons for non-adoption of crops in South Dakota, 2016-17

Ranking	Reasons For Not Using Cover Crops	Score
1	Planting time conflicts with harvest of cash crop	3.07
2	Satisfied with current practices	2.86
3	Uncertain about yield benefits	2.4
4	Not profitable	2.37
5	Uncertain about the environmental benefits	2.25
6	Risky investment	2.2
7	Federal programs are unattractive	2.15

Source: Author's Survey

Data presented in Tables 1 and 2 shows that "Improves soil health", "Increases farm productivity", and "Improves water availability/water conservation" scored high among adopters, while "Planting time conflicts with harvest of cash crops" and "Satisfied with current practices" score high among non-adopters. It should be noted that the all of these rankings were based off of the producer's perceptions. For example, while non-adoption producers ranked "Not Profitable" 4th on the rankings with a score of 2.37, they like have not experience or data to substantiate the score. Survey data should be viewed from this lens. One interesting finding was that "Helps with livestock integration" was relatively lower on the list for all cover crop adopters. However, as we stated before, only 64.5% of cover crop adopters used them with livestock integration, primarily because they don't have livestock. By separating out the segment of producers without livestock, the difference in adoption reasons between the aggregate of cover crop producers (Table 1) and those using with livestock emerges (Table 3).

Table 3: Reasons for adoption of cover crops

among livestock producers

Ranking	Reasons For Using Cover Crops (Livestock Integration)	Score
1	Improves soil health	3.59
2	Increases farm productivity	3.59
3	Improves soil water availability/ water conservation	3.56
4	Increases farm profitability	3.28
5	Helps with livestock integration	3.26
6	Prevent soil erosion	3.03
7	Breaks pest and disease cycle	2.95
8	Suppress weeds	2.8
9	Participation in federal programs	1.74

Comparing the results from Table 1 and Table 3, the top three reasons remain the same, with scores that are virtual identical making the rankings a formality. However, "Helps with livestock integration" jumps in ranking and increases its score by approximately 18%. More striking is the increase in "Increases farm profitability" jumps in ranking from 8th to 4th and the score increases by over 52%. The data shows that those producers who are integrating livestock see value in doing so, enough to increase their average score by an additional ~18%. The data also tells us that producers are doing so for profit motivations as well. The large increase in the score for "Increases farm profitability" (~52%) tells us livestock integrators are using cover crops for the same top reasons as other cover crop adopters, but are doing so with profitability as a top driver as well.

The data also tells us the main reason for not using cover crops for nonadopters is timing conflicts with cash crops. Corn and soybeans can present challenges for using cover crops, especially with livestock integration. There are opportunities to seed cover crops after corn silage and soybeans, but growth can be limited by less heat units and daylight, as well as moisture availability. However, small grains do present an excellent opportunity to combine the use of cover crops and livestock integration. Producers using cover crops after small grain production maximize forage yield potential due to a longer growing season and a greater potential for precipitation, while still harvesting a cash crop.

The SDSU Southeast Research Farm in Beresford has been collecting data on cover crop forage yields after small grains for the last several years. Data collected from 2010-2016 of dry matter (DM) after small grains show an average of 2,262 lbs. DM/acre. The range has been anywhere from 0 (2012) to 4540 (2013) lbs. of DM/acre. There is an upward trend in the forage yields, with the last 4 years averaging 3,031lbs./acre or about 1.5 DM tons/acre (Sexton, 2017). Using the yield estimate of 1 to 1.5 DM ton/acre, and assuming a utilization rate of 50% (can vary depending on the intensity of grazing management), actual feed available can range from 0.5-0.75 DM tons/acre. If using a hay DM value of $90/ton, the potential direct gross return could be between $45-$67.50/acre. Most cover crop mixes will cost between $10-40/acre, depending on the type and complexity of the mix, plus seeding. As shown above, the forage value alone can cover seed costs for cover crops.

Another way to evaluate this is on a per head basis. The researchers at the Southeast Research Farm conducted some field trials that focused on the different options for grazing livestock on cover crops during the 2016 crop year. One specific treatment was planting a cover crops after small grains, wheat and rye. A cover crop blend was planted on July 21, 2016, consisting of radish, turnips, peas, lentils, oats, sorghum, and millet. Grazing began on September 17 and lasted through October 3, with 28 head of yearling replacement heifers on those 3.5 acres before being moved. This resulted in 448 head days or 128 head days per acre (Rops et al., 2016). To put this into perspective, by scaling these results up to an 80-acre field, if producers grazed from October 1 – November 30 (61 days), and assuming no additional forage growth potential, this field would support about 98 head of breeding stock, or roughly 50 Animal Units Monthly (AUM).

Other variable expenses should be considered as well, such as costs to prepare the ground and seed the cover crop, fencing costs, and labor. The seeding costs are dependent on the capabilities of the producer, whether he can seed the cover crop or not. Fencing is also dependent on the producer's situation. If fields already have the fencing available, then the cost is very small. If fencing is not available, there are options for temporary, high tensile fences that can be installed and removed rather quickly and easily. This will add expense and increase labor hours, but if this is part of a long-term strategy, the capital costs could be spread out over several years. To best utilize the forage, it is suggested to paddock the field and mob graze to minimize trample loss. These additional costs could be offset by the value of not having cattle in a yard and reducing the time spent feeding, bedding, and cleaning, all of which increases machinery and labor costs. By grazing the animals on cover crops into late fall, producers are able to have their livestock feed themselves, spread their own manure, and maintaining their own bedding situation.

The Southeast Research Farm also conducted some research pertaining to corn yields following cover crop use and livestock integration. The conclusions from their work highlighted three main points of interest. First, there was no detrimental effect to the following year's corn yield after any of the cover crop mixes they used. Second, there appears to be a positive correlation between corn yields and the proportion of broad leaves in the cover mix, and heavy grass mixes had a neutral impact on yields. Third, a weak trend was noticed of the following corn crop need for less nitrogen, but the authors suggested further research should be done to substantiate the findings (Sexton et al., 2016). These findings add support to the potential benefits of cover crop use, adding additional value that will improve producers' bottom line.

These are just the a few of the clearly measurable benefits of cover crop use with livestock integration. Other potential benefits include increased fertility, reduced weed pressure, and an overall increase in soil health due to the synergy from adding livestock and a polyculture of plant species back into the soil. For a livestock producer who wants to start using cover crops in his/her operation, adding cover crops with livestock integration is a practice with minimal risk, but with the potential to benefit the overall success of the whole farming operation.

References

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