The Relationship between Conservation and Precision Agriculture Adoption on South Dakota Farms: Results and Preliminary Analysis from 2016 Producer Survey

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Abstract

Conservation in agricultural regions has been an increasing goal of local, state, and federal government entities in the United States since the dust bowl era of the 1930's. Technology advances over the years have contributed to more conservational 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. The 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 Dakotan farmer 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 producers adoption decisions; and 3) examine the relationship between producers' adoption decisions on conservation agriculture and precision agricultural technology practices. Survey data was cross-referenced with existing NASS data and NRCS CSP data to draw conclusions. Economic analysis using multinomial logit and bivariate probit models are employed to help identify relationships between various conservation and precision bundles as well as an overall connection between the two practices.

Conservation in agricultural regions has been an increasing goal of local, state, and federal government entities in the United States since the dust bowl era of the 1930's. Technology advances over the years have contributed to more conservational 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. The study expands on this theme, evaluating the connection between conservation and the increased use of various precision agriculture technologies.

Background and Literature Review

Precision Agriculture

Precision Agriculture Technology (PAT) is a ubiquitous term that covers many different aspects of agriculture, ranging from livestock production to grain and seed oils to fruit and produce production. A definition given by the National Resource 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). Our study focuses on its application regarding mainly 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 systems (VRS), Global Positioning System (GPS) guidance systems, yield monitor (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 decade. Lambert et al focus was on adoption of bundled technologies in Cotton growers, finding higher adoption rates among larger operators on higher yield potential ground closer to export markets (Lambert et al, 2015). In a 2011 United States Department of Agriculture Economic Research Service bulletin, Schimmelpfennig and Ebel give a comprehensive overview of the state of PAT adoption in the US, focusing on yield monitors and GPS maps, guidance systems, and variable-rate application technologies (Schimmelpfennig and Ebel, 2011). As the technology has been advancing, adoption has been increasing, 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, producers were still hesitant on adoption of new PA technologies. Schimmelpfennig continues this work with a 2016 follow up USDA ERS bulletin. Again, he focused on the previously mentioned technologies. His research showed a higher adoption rate among corn and soybean producers, along with higher adoption rate among larger farms. Like the first bulletin, 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). However, another study showed that even if technology adoption is profitable, the rate of return might not be high enough to entice producers to adopt the technology (Tozer, 2009).

Conservation Agriculture

Conservation Agriculture (CA) is any agricultural practice that either reduces the amount of inputs consumed or externalities created. Benefits from inputs reduction can be measured against a standard practice profitability, however externalities are harder to measure using this method.

Producers 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. The three conservation practices we choose to focus on are cover crops, no-till and/or strip-till, and crop rotation.

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) 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 Resource Conservation Service (NRCS) Environmental Quality Incentive Program (EQIP) positively correlated with the financial incentives of the program. (Miller, 2014)

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 producers 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 economic cost of owning the land and 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 producers. 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 increase higher managerial requirements are needed that limit the producer'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).

Data and Methods

Data

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

Producers 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, Hutchinson, Pennington, and Potter. To have a balanced cross section of producers, 800 were designated towards corn and soybean producer counties and 400 towards wheat only counties. Using this method allowed for some overlapping responses from wheat producers in the top corn and soybean producing counties, while increasing the response of wheat producers overall in wheat counties to have a more balanced response. Producers were then selected by random, with a target weight of approximately 21% of producers chosen from each corn and soybean county, and approximately 30% of producers from each wheat county. 1200 surveys were sent out January 27, 2017 to 14 primary counties, with responses from producers that identified as primarily farming in 28 counties (Table 1). Of the 1200 surveys, 37 were returned to sender, 59 were returned by recipient with no or insufficient data, and 198 contained usable data.

Producer characteristics

The average age of the overall producer 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 operator from the 2012 Agriculture Census. (USDA, 2012) The average farm size was 2,667.1 acres overall, with 1905.4 acres in crop production, 600.5 acres in pasture, 108.8 in hay acres, and 52.3 acres in some federal reserve program. 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 producers 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. Producers with any form of off-farm employment were at 22.5%, lower than the 2012 Agriculture Census figure of 56.1 %. We believe this discrepancy of our producer respondents being larger is attributed to lower off-farm employment rates and an older age that census data. Additional data 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 producer’s operation (51.5%). This data can be viewed in aggregate in Table 2.

Because of the producer’s reluctance and sensitivity to personal financial disclosures, we chose to collect this data 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 average score was 3.19, with category 4 have in the largest portion of producers (26.8%). The total distribution of producers is shown in Table 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 producers (28.9%) followed by category 4 (26.9%). The total distribution is shown in Table 2.

Overall adoption rates for our main precision variables were, YM (68.7%), GPS (76.3%), and VRS (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 producer (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 actual adoption rates for various reason. One reason may be that the average farm size was larger than USDA estimates. Since 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 producers who had off-farm employment in our survey (22.5%), which would imply a greater number of producers with farming as their primary occupation.

There were three conservation agriculture (CA) practices primarily focused on in this study, crop rotation, cover crop use, and no-till or strip-till adoption. Crop rotation data was collected by first asking whether the producer 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 producers that had a rotation greater than two crops, which was labeled a "true crop rotation" (TCR). Using the TCR variable, the percentage of producers using more than two crops in a rotation dropped to 35.9%. Wheat was the most likely third crop (26.3%) followed by alfalfa (4.5%). The percentage of producers using cover crops was at 31.3%. Of those who used cover crops (CC), 64.5% grazed the (CC) that season. Again, with no-till and/or strip till (NTST), a variable was created to capture the use of both farming methods. Because both practices promote minimal soil displacement, we felt it was 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 producer used NTST and another practice, they were still counted as a NTST adopter. Using these criteria, 55.5% of the survey respondents used NTST in their operation.

Producer Characteristics by Practice

For further analysis of producer characteristics, using seven different variables, producers 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 VRS) and three CA variables (TCR, CC, NTST) plus one for participation in the Conservations Stewardship Program (CSP). Capturing any variations in the general statistically differences between adopters and non-adopter would allow us to focus further 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 Table 2.

Yield Monitor (YM) Adoption

Overall YM adoption was 68.7%. Using the same descriptive methodology as before, producers who adopted YM were the mean was 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 producer 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 Systems (VRS) Adoption.

Overall VRS 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 income was lower for adopters versus non-adopters and raising cattle lower for adopters as well. And interesting finding was that VRS 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 producers 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 VRS adopters, however VRS 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 VRS 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 producers 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 our modeling for further analysis.

True Crop Rotation (TCR) Adoption

Overall TCR adoption rates were 35.9% of our producer respondents. TCR 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 income (10.5% vs 29.2%). TCR adopters were also more likely to have cattle. TCR 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 producer 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 our 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 producer 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 producer 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 income, 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 producers deciding to diversify through off-farm employment or raising livestock. Also, it's not surprising that producers with more off-farm income would farm less acres, which we see a negative correlation as well. Another constant was 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 income.

A cross tabulation table (Table 3) 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 increase the likelihood of another practice. This is 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.

Conservation Stewardship Program in South Dakota

The Conservation Stewardship Program (CSP) is a conservation program approved in the 2008 Farm Bill that pays producers 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 producer is willing to implement on their operation. Enhancements can range from increased use of precision technologies such as YM, GPS, and VRS 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 rotation to name a few. 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 farmer 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 2,881 total South Dakota farmer 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 4)

CSP Adoption

The number of farmers involved in CSP was 42 or about 21.2%. Farmers involved in were on average 56 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

Multinomial Logit Model

We have employed a multinomial logit model that uses random utility framework to answer the underlying question of producer'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 producer 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 producer can be specified as follows:

$$V_{ij} = X_{ij}\beta + \varepsilon_{ij} \quad (1)$$

where V_{ij} is the utility for producer i choosing conservation bundle j, $X_{ij}\beta$ is the observed components, ε_{ij} is the unobserved component of the utility function, and X_{ij} is the vector of covariate variables which are assumed to be linear. Producer i will choose conservation bundle j subject to the following constraints:

$$V_{ij} \geq V_{ik} \qquad for\ \forall\ j \neq k \quad (2)$$

$$X_{ij}\beta + \varepsilon_{ij} \geq X_{ik}\beta + \varepsilon_{ik} \quad (3)$$

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

$$P_{ij} = \frac{e\,Vij}{\sum_{j=1}^{J} eVij} \quad (4)$$

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 dependent variable and independent variables. We have used the multi nominal logit model to understand producers' precision technology adoption decisions as well. For our study, we focus on three precision technologies; GPS, variable rate systems (VRS), and yield monitor (YM). As in the case of conservation practices, farmers can choose from one of the eight mutually exclusive choice sets: GPS only, VRS only, YM only, VRS&GPS, VRS &YM, YM&GPS, VRS, 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 choose among conservation practices and precision technologies, we can model producers' adoption decision as a 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 producers 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 producer's decision process is modeled using the random utility framework. From the utility theoretic standpoint, a producer is willing to adopt a new technology/practice if the producer's utility with the new technology/practices, minus its cost, is at least as great as the old technology/practices—that is, if

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

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 producers; and $\mathbf{X}$ is a vector of independent variables.

The producer'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

$$V(1, Y_1 - C; \mathbf{X}) + \upsilon_1 \geq V(0, Y_0; \mathbf{X}) + \upsilon_0, \quad (2)$$

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

$$Y_1^* = \beta_1'\mathbf{X}_1 + \upsilon_1, \quad (3)$$

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

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

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

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

Results

The conservation agriculture (CA) bundles were numbered 1-8. Table 5 explains the bundle make-up and results. The Precision Agriculture Technology (PAT) bundles were also numbered 1-8. Table 6 explains the bundle make-up and results. The practice bundles were regressed against seven farmer characteristics; Higher quality land (HQL), Cropland farm size, CSP, age, education score, off-farm income, and a cattle operation, plus a constant.

High-Quality Land Variable

South Dakota topography and soil quality change throughout the state. To capture the difference in quality of cropland, a high-quality land (HQL) 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. A threshold of $170 per acre county average was set, with any county at or above this point being considered "high-quality 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 may move this line to further the relationship in land quality and adoption practices.

Conservation Bundles

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 the soil type of HQL. This type of land is typically heavier soils that farmers tend to be more comfortable 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 income and TRC. For the farmer with off farm income, a rotation of more than 2 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 typical a requirement for most cow-calf operators. Management of this land directly effects the long-term viability and productivity of the land, so producers 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.

Precision Bundles

There were three notable results from this analysis. The first was off farm income 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 was CSP adoption became significant. Although a negative coefficient was observed on PAT bundle 3, but PAT bundles 6 and 7 had 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 three PAT bundles had positive coefficients at the 10% level, PAT bundle 4, 6, 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. Further analysis needs to be done on this to further understand this relationship.

Bivariate Results

Results mostly supported our hypothesis (Table 7). One of the most significant results was HQL had a negative effect on CA. As discussed earlier, because producer in HQL 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 presents of a cattle operation compared to HQL. As discussed earlier, producers with cattle are may be more conservation minded for various reasons. As for PAT, we saw significant results for age and off-farm income. 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 sign associated with its coefficient, although not significant. This was an aspect that surprised us. 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, we consistently saw no effect. Further analysis will be done to determine the cause of this. The other surprising result was the coefficients for CSP, although not significant, were negative for CA and positive for PAT. Further analysis will also be done on these results.

Conclusion

From this preliminary analysis, we found significant positive effects between CA and cattle operations and a significant negative effect between CA and HQL. We also saw that off-farm income negatively effects the more labor-intensive and possibly more capital-intensive practice of TCR. As for PATs, off-farm income 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, 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. These results were from preliminary analysis, and further analysis in the future will be done to better understand the relationships we are observing.

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List of Tables

Table 1

South Dakota Counties Represented ***(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

Table 2

South Dakota Producer Characteristics by Adoption Decisions

		Precision Agriculture Technology (PAT)						Conservation Agriculture (CA)						Conservation Stewardship Program (CSP)	
		Yield Monitor (YM)		GPS		Variable Rate Systems (VRS)		No-Till/Strip-Till (NTST)		True Crop Rotation (TCR)		Cover Crops (CC)			
	Overall	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Age (Years)	59.45	58.37	61.79	58.82	61.65	57.21	61.72	58.65	60.47	61.01	58.55	58.19	60.04	55.95	60.41
Off farm employment	22.5%	17.3%	32.8%	19.3%	34.0%	19.8%	24.5%	20.2%	25.3%	10.5%	29.2%	12.5%	26.7%	26%	21.5%
Spouse off farm	54.3%	53.1%	57.1%	51.0%	64.4%	56.4%	52.2%	51.9%	57.1%	51.5%	55.8%	55.9%	53.5%	62%	51.4%
Primary Decision Maker (Years)	30.50	29.54	32.24	30.49	31.13	29.01	31.85	29.20	32.38	29.52	31.00	28.33	31.50	28.32	31.12
Raise Cattle	51.5%	48.1%	59.0%	53.0%	47.9%	45.9%	58.2%	57.3%	44.3%	63.4%	44.9%	64.5%	45.6%	47.6%	52.6%
Cow/Calf	46.0%	42.2%	51.6%	46.7%	44.7%	40.4%	49.5%	56.9%	42.3%	60.9%	44.1%	67.2%	26.3%	45.2%	46.2%
Federal/State Conservation Incentive Payments	31.6%	30.8%	32.8%	33.1%	26.1%	44.1%	18.9%	41.5%	19.0%	32.4%	31.1%	49.2%	23.3%	100.0%	12.8%
Owned Acres	1,353.6	1,445.0	1,166.5	1,522.8	825.8	1,492.3	1,223.6	1,557.0	1,108.6	1,867.0	1,063.7	2,043.8	1,037.0	1421.325	1336.0
Rented Acres	1,322.2	1,629.1	663.4	1,554.5	570.4	1,707.4	948.0	1,734.9	829.6	1,494.6	1,226.2	2,019.2	1,007.7	1728.625	1431.0
Cropland Acres	1,905.4	2,316.7	1,023.0	2,223.7	893.4	2,356.7	1,471.4	2,296.6	1,416.5	2,412.4	1,622.0	2,725.1	1,531.8	2440.0	1784.4
Pasture Acres	600.5	575.5	648.4	680.4	370.5	709.9	488.5	792.5	354.9	680.5	556.1	1,153.7	344.6	569.5	827.7
Hay Acres	108.8	105.6	115.7	112.9	95.6	93.4	124.3	122.3	92.4	157.0	82.6	161.0	84.7	105.3	168.5
Federal Conservation Program Acres	52.3	64.4	28.1	61.8	22.7	71.3	34.8	63.7	38.5	94.6	29.0	99.8	30.5	141.6	96.5
Average Farm size (Acres)	2,667.1	3,062.3	1,815.2	3,078.7	1,382.2	3,231.4	2,119.0	3,275.2	1,902.3	3,344.4	2,289.7	4,139.6	1,991.6	3256.4	2877.1
Gross Income	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Less than $149,999	15.6%	6.7%	33.9%	9.0%	34.8%	5.7%	25.6%	11.2%	21.0%	6.1%	21.2%	5.3%	20.5%	2.6%	22.1%
$150,000-$399,999	19.6%	13.4%	30.5%	16.4%	30.4%	17.0%	21.1%	15.3%	24.7%	16.7%	21.2%	17.5%	20.5%	17.9%	17.4%
$400,000-$749,999	17.9%	17.6%	18.6%	17.2%	19.6%	15.9%	20.0%	21.4%	13.6%	15.2%	19.5%	17.5%	18.0%	20.5%	15.1%
$750,000-$1,499,999	26.8%	38.7%	3.4%	33.6%	6.5%	38.6%	15.6%	31.6%	21.0%	30.3%	24.8%	22.8%	28.7%	35.9%	25.6%
$1,500,000-$2,499,999	11.2%	12.6%	8.5%	12.7%	6.5%	8.0%	14.4%	12.2%	9.9%	25.8%	2.7%	21.1%	6.6%	10.3%	10.5%
$2,500,000 or Greater	8.9%	10.9%	5.1%	11.2%	2.2%	14.8%	3.3%	8.2%	9.9%	6.1%	10.6%	15.8%	5.7%	12.8%	9.3%
Score	3.20	3.61	2.37	3.50	2.26	3.62	2.79	3.33	3.04	3.66	2.93	3.84	2.90	3.72	3.12
Education	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Less than High School/GED	2.8%	3.7%	1.6%	2.7%	4.2%	2.0%	4.1%	2.8%	3.4%	5.6%	1.6%	1.6%	3.7%	2.4%	3.1%
High School/GED	22.0%	29.1%	27.9%	29.3%	29.2%	31.6%	25.8%	22.0%	37.5%	29.6%	28.6%	24.2%	31.1%	19.0%	31.3%
Some College	30.3%	24.6%	18.0%	24.7%	14.6%	22.4%	22.7%	30.3%	12.5%	25.4%	20.6%	21.0%	23.0%	23.8%	25.0%
Occupational/Associates Degree	13.8%	11.2%	19.7%	14.7%	10.4%	12.2%	15.5%	13.8%	13.6%	9.9%	15.9%	11.3%	14.8%	14.3%	9.4%
Bachler's Degree	26.6%	26.1%	27.9%	24.0%	35.4%	28.6%	24.7%	26.6%	27.3%	22.5%	29.4%	35.5%	23.0%	35.7%	26.0%
Graduate/Professional Degree	4.6%	5.2%	4.9%	4.7%	6.3%	3.1%	7.2%	4.6%	5.7%	7.0%	4.0%	6.5%	4.4%	4.8%	5.2%
Score	3.48	3.43	3.59	3.42	3.63	3.43	3.53	3.53	3.41	3.35	3.55	3.74	3.36	3.76	3.40

Source: Author's Survey

Table 3														
Cross Tabulation of Adoption Rates of Precision Agriculture Technologies (PAT) and Conservation Agriculture (CA) Practices														
Practice		Yield Monitor (YM)		GPS		Variable Rate Systems (VRS)		No-Till/Strip-Till (NTST)		True Crop Rotation (TCR)		Cover Crops (CC)	
Dependent Variable	Adoption	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Yield Monitor (YM)	Yes	100.0%	0.0%	94.1%	5.9%	63.7%	36.3%	60.7%	39.3%	37.0%	63.0%	31.1%	68.9%
	No	0.0%	100.0%	33.9%	66.1%	19.4%	80.6%	41.9%	58.1%	33.9%	66.1%	30.6%	69.4%
GPS	Yes	84.9%	15.1%	100.0%	0.0%	59.9%	40.1%	63.2%	36.8%	36.8%	63.2%	32.9%	67.1%
	No	14.9%	85.1%	0.0%	100.0%	17.0%	83.0%	31.9%	68.1%	31.9%	68.1%	25.5%	74.5%
Variable Rate Systems (VRS)	Yes	86.9%	13.1%	89.9%	10.1%	100.0%	0.0%	61.6%	38.4%	34.3%	65.7%	35.4%	64.6%
	No	49.5%	50.5%	59.6%	40.4%	0.0%	100.0%	47.5%	52.5%	37.4%	62.6%	26.3%	73.7%
No-Till/Strip-Till (NTST)	Yes	75.5%	24.5%	86.4%	13.6%	56.4%	43.6%	100.0%	0.0%	40.0%	60.0%	40.9%	59.1%
	No	26.8%	73.2%	27.8%	72.2%	18.7%	81.3%	0.0%	100.0%	13.6%	86.4%	8.6%	91.4%
True Crop Rotation (TCR)	Yes	70.4%	29.6%	78.9%	21.1%	47.9%	52.1%	62.0%	38.0%	100.0%	0.0%	43.7%	56.3%
	No	67.7%	32.3%	74.0%	26.0%	51.2%	48.8%	52.0%	48.0%	0.0%	100.0%	24.4%	75.6%
Cover Crops (CC)	Yes	69.4%	30.6%	80.6%	19.4%	58.1%	41.9%	72.6%	27.4%	50.0%	50.0%	100.0%	0.0%
	No	68.4%	31.6%	73.5%	26.5%	46.3%	53.7%	80.9%	19.1%	29.4%	70.6%	0.0%	100.0%
Source: Author's Survey													

Table 4								
Conservation Stewardship Program (CSP) 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.								

Table 5

Multinomial Logit Results for Conservation Bundles

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

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

Table 6

Multinomial Logit Results for Conservation Bundles

	Precision Agricultural Technology (PAT) Practice Adoption Bundle	Higher Quality Land (HQL)	Cropland Farm Size	Off farm Income	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 System (VRS)	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	VRS & 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	VRS & 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	VRS, 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

Table 7

Bivariate Results of Conservation Agriculture and Precision Agriculture Technology Bundles

Farmer Characteristic/Adoption	Higher Quality Land (HQL)	Cropland Farm Size	Conservation Stewardship Program (CSP)	Age	Education	Off farm Income	Cattle Operation	Constant	Adoption rate (%)	rho
Conservation Adoption	-0.69461 ***	-5.7E-05	-0.22274	-0.0128	-0.04311	-0.34843	0.698905 ***	1.720351	72%	0.2840 ***
	(0.2165)	(0.0000)	(0.2522)	(0.0082)	(0.0740)	(0.2514)	(0.2174)	(0.6205)		(0.1334)
Precision Agriculture Technology Adoption	0.109817	-1.7E-05	0.264508	-0.02238 **	-0.05411	-0.65425 ***	-0.29996	2.462353	75%	
	(0.2139)	(0.0000)	(0.2602)	(0.0088)	(0.0754)	(0.2502)	(0.2098)	(0.6785)		

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