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# Cover-Crop Usage in South Dakota: Farmer Perceived Profitability and Future Adoption Decisions

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# Cover-Crop Usage in South Dakota: Farmer Perceived Profitability and Future Adoption Decisions

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Using bivariate ordered logit models, we investigate factors that determine farmers' perceptions of cover-crop profitability and likelihood of future usage in the climate transition zone of the Northern Great Plains. Our results indicate that approximately 40% of long-term (10+ years) users perceived a profit increase of more than 5%. Additionally, future adoption decisions are positively affected by environment-oriented attitudes and negatively affected by prioritizing short-term profitability. More efforts can be directed toward educational programs that enhance understanding of the short- versus long-term economic benefits of cover crops.

*Key words*: bivariate ordered logit model, conservation practice, factor analysis, future adoption likelihood

## Introduction

The use of cover crops as a conservation practice protects the soil surface during periods between the harvest and planting of cash crops. Given their potential to efficiently reduce water pollution and build soil health and resilience, cover crops are receiving increasing attention from farmers, researchers, and policy makers (Sullivan, 2003; Kaspar and Singer, 2011; Chatterjee, 2013). A decade ago, only 18% of farmers in the U.S. Corn Belt (Singer, Nusser, and Alf, 2007). In recent years, the cover-crop adoption rate has grown, with more farmers realizing the benefits of using them. Estimates of cover-crop adoption during the past decade across the Midwestern Corn Belt, as well as the United States as a whole, reveal substantial increases in acreage. For example, Seifert, Azzari, and Lobell (2018) noted an increase of 94% in cover-crop planted acres from 2008 to 2016. Moreover, the fifth annual Sustainable Agriculture Research and Education–Conservation Technology Information Center (SARE–CTIC) cover-crop survey from 48 U.S. states reported that the nation's farmers increased cover-crop plantings from 218,000 acres in 2012 to 691,000 acres in 2017.

There are many reasons for growing interest in cover crops. Improvements in soil fertility and structure are considered the primary reasons for adoption among cover-crop users (Mallory, Posner, and Baldock, 1998; Reimer, Weinkauf, and Prokopy, 2012; Conservation Technology Information Center, 2017; Bergtold et al., 2019; Plastina et al., 2020). Cover crops may also suppress weeds and reduce pest pressures, run-off, soil erosion, and tillage requirements while improving water quality

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and sequestering carbon (Dabney, 1998; Dabney, Delgado, and Reeves, 2001; Clark, 2007; Delgado et al., 2007; Singer, Nusser, and Alf, 2007; Conservation Technology Information Center, 2017). In addition to soil and environmental benefits, many studies mention economic incentives as an important factor increasing cover-crop adoption across the U.S. Corn Belt (Singer, Nusser, and Alf, 2007; Reimer, Weinkauf, and Prokopy, 2012; Roesch-McNally et al., 2018; Plastina et al., 2020). Lichtenberg (2004) noted that economic factors such as increased profit due to higher crop yield and additional revenue from haying and grazing have a substantial influence on conservation practice adoption. In addition, factors that affect the adoption of cover crops include risk management considerations and agricultural policies that provide financial incentives or technical assistance to adopters (Bergtold et al., 2019). One such example is a 3-year demonstration program established by the Iowa State Department of Agriculture and Land Stewardship that reduced the insurance premium by $5/acre for eligible cover-crop users in 2018 (Rausch, 2017). Despite the cost-share programs, Plastina et al. (2020) found that short-term usage of cover crops reduced profitability, but farmers continued using cover crops because of their perceived long-term benefits.

An individual farmer's decision to incorporate conservation practices such as cover crops can also be influenced by educational events such as conferences, demonstration sites and field days, and training as well as technological infrastructure that supports cover-crop use (Singer, Nusser, and Alf, 2007; Arbuckle and Roesch-McNally, 2015; Plastina et al., 2020). Livestock integration is also an important factor in driving cover-crop use, as cover crops enhance forage opportunities for livestock operations (Singer, Nusser, and Alf, 2007; Arbuckle and Roesch-McNally, 2015). Farmers who integrate diversified crop rotation in their farm operation are also more likely to utilize cover crops (Singer, Nusser, and Alf, 2007; Arbuckle and Roesch-McNally, 2015; O'Connell et al., 2015; Singh et al., 2018; Chalise et al., 2019).

Despite the growing interests and benefits, farmers can easily discontinue cover-crop use if they do not receive benefits that justify its usage. Dunn et al. (2016) found that farmers in the western United States are likely to discontinue cover-crop use due to perceived high costs and difficulties integrating it into their cropping systems. Although little is known about the overall levels of discontinuance among cover-crop users, the year-to-year percentage of cover-crop users who discontinued the practice increased from 3% in 2010 to 8% in 2013 (Dunn et al., 2016).

A growing literature in economics and sociology seeks to better understand factors behind the sustained use and adoption of conservation practices, with a focus on cover crops (Singer, Nusser, and Alf, 2007; Bergtold et al., 2012; Reimer, Weinkauf, and Prokopy, 2012; Arbuckle and Roesch-McNally, 2015; O'Connell et al., 2015; Dunn et al., 2016; Burnett et al., 2018). These studies examined how cover-crop adoption is affected by the characteristics of farmers and their operations. There is, however, very limited research on the factors that affect producers' actual and perceived profitability from cover-crop usage and how these factors affect future likelihood of adoption. Moreover, very little is known about how different lengths of adoption may affect farmers' perceptions of profitability and future adoption decisions.

Cover-crop system adoption and its associated benefits vary with rotation, soil characteristics, and climatic regime. For example, while cover crops facilitate successful planting by absorbing excessive soil moisture in mesic regions, they reduce the amount of water available to the cash crop in arid and semiarid regimes (Reese et al., 2014; Robinson and Nielsen, 2015; Nielsen et al., 2016). Compared to warm regions, cover-crop benefits may also be limited by the shorter growing season in frigid environments (Reese et al., 2014). Such spatial variability in cover-crop performance necessitates an examination of the benefits and use decisions of cover crops on a regional basis, especially where cover-crop performance might be restrained by short growing season and water stress.

This paper fills a void by examining factors affecting farmers' actual and perceived cover-crop profitability and future usage likelihood in the transition zone between mesic and frigid soil temperature regimes and humid and semi-arid climate regimes. Specifically, we test the hypothesis that cover-crop usage duration is positively associated with (i) farmers' perceptions of increased profitability and (ii) greater likelihood of cover-crop usage in the future. Survey data collected from farm operators in eastern South Dakota is analyzed. Our study region is located on the Western Corn Belt and within the Northern Great Plains climate transition zone, which exhibits a distinct east–west declining average precipitation gradient, with intensive cropping operations in the east and more prevalent grassland toward the west (Wang et al., 2017).

## Materials and Methods

### *Survey Description*

The data used in this study were obtained from a survey of farm operators located in eastern South Dakota in the spring of 2018. The dominant rotations in the region are either 2-year rotation (corn–soybean) or 3-year rotation (corn–soybean–wheat). Cover crops were generally planted following the cash crop in August (wheat) or November (corn and soybean). The survey contained sections on knowledge and information about soil conservation practices, experience with their usage and future intentions, benefits and challenges associated with adoption of those practices, and questions about farmers' perceptions of cost and profits following their possible or actual adoption. The list of eligible farming operations consisted of participants in Farm Service Agency (FSA) programs. In 2017, 43,487 out of 49,547 South Dakota producers participated in FSA programs, indicating a participation rate of approximately 87.8%.[1]

The questionnaires were sent to a representative sample of 3,000 farm operators identified using proportionate stratified-random sampling. The selected farmers were contacted in four rounds. First, the participants were contacted by letter with a link to answer the online questionnaire and information about the survey.[2] Those who did not respond in the first round were then mailed the paper questionnaires with stamped return envelopes, followed by a reminder postcard, and a second mailing of the questionnaires at 2-week intervals. Excluding operations that stopped farming or rented out all of their land, the final dataset used in this study consisted of 708 returned questionnaires, for a 30% response rate. Figure 1 displays average adoption rate of cover crops with the number of respondents included for each surveyed county.

### *Data Description*

The two dependent variables to be modeled—perceived profitability change and future likelihood of cover-crop adoption—are ordinal in nature. Specially, regarding change in perceived profitability, we label 1 "reduced by more than 5%," 2 "no major change (within 5%)," and 3 "increased by more than 5%." For future adoption, we label 1 "not at all likely," 2 "somewhat or moderately likely," and 3 "very or extremely likely." Based on the crop budget in our study region,[3] east and central South Dakota, the net return averaged \$237/acre for corn and \$190/acre for soybean, with an average annual net return of \$214/acre for the conventional corn–soybean rotation in the region. In this context, major changes in profitability ($\geq$5%) exceed \$11/acre.

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[1] The numbers of producers and FSA participants in South Dakota were obtained from the 2017 Ag Census and personal communication with a FSA program specialist, respectively. The 2017 Ag Census defines a producer as a person involved in making farm operation decisions, who could take the role of "an owner, member of the owner's household, a hired manager, a tenant, a renter or a sharecropper" (U.S. Department of Agriculture, 2017b), while the FSA defines a producer as "an owner, operator, landlord, tenant or sharecropper" (https://www.fsa.usda.gov/Internet/FS_File/1arcplc4.pdf). Note that the 2017 Ag Census considers a landowner to be a producer only if he or she retains the land for his or her own operation, while the FSA definition has no such restriction. Therefore, the FSA definition of landowner could be broader, which implies that the FSA participation rate in South Dakota as of 2017 could be slightly lower than 87.8%.

[2] Half of the sample was randomly selected to receive a \$2 bill preincentive to test whether receiving this increased the likelihood of response to the survey, which it did (Avemegah et al., 2021).

[3] https://extension.sdstate.edu/crop-budgets [Accessed June 2, 2020].

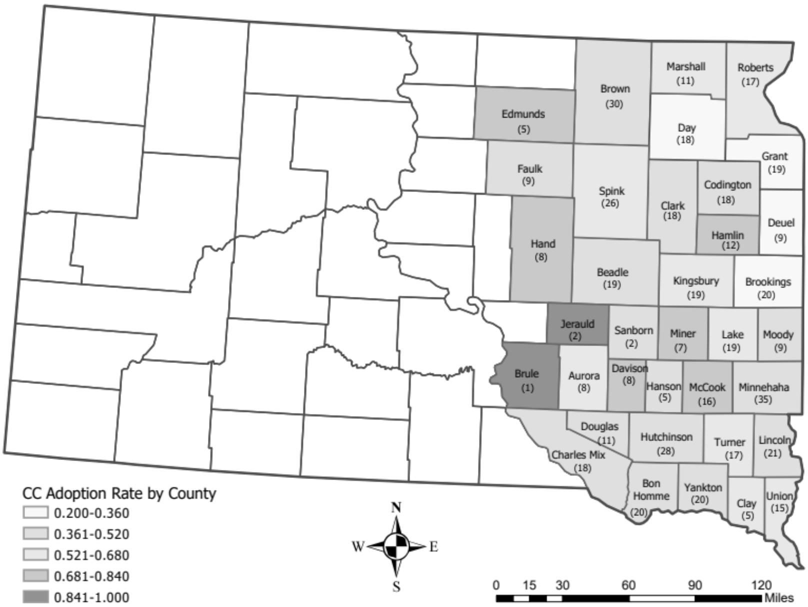


**Figure 1. Cover-Crop Adoption Rates by County with Number of Respondents Indicated in Brackets, Based on 2018 South Dakota Farmer Survey**

Note that the profitability change following cover-crop adoption could vary substantially by location, management, and weather (Bergtold et al., 2019). In east South Dakota, Tobin et al. (2020) found that cover-crop adoption involving grazing increased the profit by \$17.23/acre and \$43.61/acre in the first and second years, respectively. Similarly, Sustainable Agriculture Research and Education (2019) estimated that grazing cover crops increases profits by \$17.87/acre, \$50.65/acre, and \$67.13/acre, respectively, in the first, third and fifth years after adoption. Without grazing, Sustainable Agriculture Research and Education showed that profits were reduced by \$31.36/acre in the first year and increased by \$1.42/acre and \$17.90/acre in the third and fifth years, respectively. Regarding the benefit of cover crops without grazing, the no-change scenario (i.e., changes not exceeding 5% or \$11/acre in our context) is generally true for short-term users. The 5% threshold, therefore, allows us to distinguish the cover-crop benefits perceived by short- and long-term users.

We included years of cover-crop usage in the model to test whether longer duration of usage is associated with an increase in perceived profitability and future likelihood of adoption. Years of usage are denoted by five categories, with 0 to 4 denoting "never used," "<3 years," "3–5 years," "6–10 years," ">10 years," respectively. Compared to other farm conservation practices, cover cropping is a more recently promoted practice—0.936 years of usage—falling into the "<3 years" category (Table 1).

Cover crops, when used to graze cattle, can be an economically viable practice when implemented under the right conditions because doing so reduces forage costs (Higgins, 2017; Tobin et al., 2020). In this paper, we included grazing potential as an explanatory variable, which takes a value of 1 if producers either identify themselves as using integrated crop and livestock systems (ICLS) or have pastures available, so that cover crops can be potentially used for grazing, and 0 otherwise; most farmers (71.1%) in our study region selected 1 for grazing potential (Table 1). Livestock grazing on cropland mostly occurs after grain harvest in the Northern Great Plains, taking forms such as crop residue grazing and cover-crop grazing (Kumar et al., 2019). A 19-state survey conducted in 2010 found that South Dakota ranked third in terms of grazed corn residue acres, surpassed only by Nebraska and Iowa (Schmer et al., 2017). Similarly, a 2016 survey of South

**Table 1. Descriptive Statistics for Variables in Bivariate Ordered Logit Model**

| Variable | *N* | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|---|
| Cover-crop profitability | 593 | 2.059 | 0.611 | 1 | 3 |
| Cover-crop adoption | 671 | 2.097 | 0.698 | 1 | 3 |
| Years of cover-crop- usage | 667 | 0.936 | 1.235 | 0 | 4 |
| Conservation-tillage adoption | 662 | 0.782 | 0.413 | 0 | 1 |
| Diversity rotation (3+ crops) | 678 | 0.236 | 0.425 | 0 | 1 |
| Grazing potential | 667 | 0.711 | 0.454 | 0 | 1 |
| Decision making years | 629 | 26.609 | 15.902 | 0 | 70 |
| Gender | 646 | 0.028 | 0.165 | 0 | 1 |
| Education (high school) | 646 | 0.251 | 0.434 | 0 | 1 |
| Education (some college) | 646 | 0.347 | 0.476 | 0 | 1 |
| Education (college degree) | 646 | 0.320 | 0.467 | 0 | 1 |
| Education (postgraduate degree) | 646 | 0.057 | 0.233 | 0 | 1 |
| Ag major/minor | 642 | 0.198 | 0.399 | 0 | 1 |
| University Extension | 690 | 2.129 | 0.706 | 1 | 4 |
| Social networks | 685 | 2.572 | 0.707 | 1 | 4 |
| Gross sales ($50,000–$99,999) | 617 | 0.152 | 0.360 | 0 | 1 |
| Gross sales ($100,000–$249,999) | 617 | 0.188 | 0.391 | 0 | 1 |
| Gross sales ($250,000–$499,999) | 617 | 0.243 | 0.429 | 0 | 1 |
| Gross sales ($500,000–$999,999) | 617 | 0.149 | 0.356 | 0 | 1 |
| Gross sales ($\geq$$1 million) | 617 | 0.099 | 0.299 | 0 | 1 |
| Cost share received | 583 | 0.396 | 0.919 | 0 | 4 |
| Precipitation | 614 | 16.523 | 1.505 | 13.279 | 19.359 |

Dakota, Nebraska, and North Dakota farmers indicated that ICLS adoption rate in South Dakota was 71.8%, slightly lower than in Nebraska (77.3%) but significantly higher than in North Dakota (58.9%) (Wang et al., 2019a).

In addition, several studies suggest that cover crops may assist in weed control in no-tillage and organic systems (Amado et al., 2006; Triplett and Dick, 2008; Mirsky et al., 2013). We included adoption status of conservation tillage (CT) in the model to capture the potential interaction effects between cover crops and other soil conservation practices, with 0 and 1 denoting nonadoption and adoption, respectively. Among survey respondents, 78.2% identified themselves as conservation tillage users (Table 1), consistent with the average conservation tillage (including no-till) adoption rate of 73.7% in South Dakota based on 2017 Agricultural Census data (U.S. Department of Agriculture, 2017a).

Moreover, farmers practicing diversified crop rotation have a lower barrier to adopting cover crops due to their equipment infrastructure and experiences with multiple crops (Singer, Nusser, and Alf, 2007; Arbuckle and Roesch-McNally, 2015). We also included a variable to denote the diversification of farmers' cropping systems, which equals 1 if the typical crop rotation involves three or more crops, and 0 if it involves two or fewer crops. We found that most respondents were using the traditional rotation pattern involving only corn and soybeans, and that 23.6% of farmers had typical crop rotations that included three or more crops (Table 1). This finding confirms that the corn and soybeans are by far the dominant crops in eastern South Dakota (Natural Resources Conservation Service, 2014). It is worth noting however, that only 40.9% of respondents reported that they had never used diversified crop rotation, implying that most producers may occasionally utilize a third or fourth crop on some portion of their farmland, but it is not their typical rotation pattern.

Farmer demographic variables—including decision-making years, education, agricultural degree, and gender—have been widely used as predictors for adoption of conservation practices (Carlisle, 2016). We include explanatory variables for operator experience, general education, major or minor in an agricultural related field, and gender. Among these, operator experience is a continuous variable with an average of approximately 26.6 years, which indicates that most survey respondents have been farming for a relatively long period. Table 1 findings report that 25.1%, 34.7%, 32.0% and 5.7% have completed "high school," "some college or technical school," "college degree," and "post-graduate degree," respectively. In addition to general education level, we inquired about whether the respondent had completed an agricultural major or minor such as agronomy, animal science, or agricultural business; this variable takes a value of 1 if producers have such a degree, and 0 otherwise. Among respondents with a college degree, 19.8% had completed an agricultural major or minor in college.

According to Weir and Knight (2004), education can be divided into three categories: formal, nonformal, and informal. In our context, general education and an agriculture major can be regarded as formal education, which aims to provide general knowledge and skill to farmers that may contribute to farm productivity. Nonformal education, such as from Extension workshops, imparts specific information about new technologies or practices. Informal education refers to farmers' peer-learning behavior, accomplished through channels such as social networks. In promoting the use of conservation practices, university Extension and social media play a major educational role (Prokopy et al., 2008; Bates and Arbuckle Jr, 2017; Manson et al., 2016; Wang et al., 2019b). To capture the educational effects, we asked farmers about their levels of agreement with the following statements: (i) "I regularly attended university Extension training workshops" and (ii) "I use my social networks to learn new innovative ideas that help develop my business." The average ratings for university Extension and social networks are 2.129 and 2.572, respectively, indicating that farmers on average do not regularly attend Extension workshops and that social networks are more important in the dissemination of new ideas.

Gender takes a value of 0 (for men) or 1 (for women). An average of 0.028 in gender means that fewer than 3% of farm operators are female, which is lower than the 8% female ratio found in Wang2019a) and much lower than the percentage of female principal producers in South Dakota, which was 29.1% based on 2017 Agricultural Census (U.S. Department of Agriculture, 2017a). Therefore, it is likely that the female farmers were underrepresented in this survey.

Previous studies have demonstrated that larger farms and higher farm returns very often play a positive role in conservation practice adoption (Featherstone and Goodwin, 1993; Fuglie, 1999; Upadhyay et al., 2002; Vitale et al., 2011). Therefore, we include variables for categories of gross sales to capture the farm-scale effect. As indicated by Table 1, most producers (24.3%) belong to the \$250,000–\$499,999 category, followed by the \$100,000–\$249,999 category (18.8%). Compared with the 2017 census, which showed that 46.4%, 9.6%, 14.9%, 12.3%, 9.0% and 7.8% of producers in South Dakota belongs to the sales value category of "lower than \$50,000," "\$50,000–\$99,999," "\$100,000–\$249,999," "\$250,000–\$499,999," "\$500,000–\$999,999," and "≥\$1,000,000," respectively (U.S. Department of Agriculture, 2017a), our survey respondents are skewed toward categories with sales of more than \$50,000. Given that our survey sample was selected from FSA program participants, this result is consistent with Reimer and Prokopy (2014), who found that farm size is positively related to participation in government conservation programs.

In addition, farmer attitudes and perceptions influence conservation practice adoption decisions (Adesina and Baidu-Forson, 1995; Wang et al., 2019a). In a series of questions, farmers were asked to report their attitudes on issues such as negative effects of chemical use, soil conservation motivation, and profit maximization priority (Table 2). For each question, they could pick from one of the four categories of responses—"strongly disagree," "disagree," "agree," and "strongly agree"—denoted by 1 to 4, respectively. Farmers' attitudes on issues under similar topics are often significantly correlated (Table A1). For example, the correlation coefficient between issue 1 ("I am concerned with how much fuel I use for farming") and issue 3 ("Chemical carry over is a concern for me") is 0.331 ($p < 0.01$). To facilitate further analysis, these attitudinal variables are generally grouped into fewer categories based on similar themes or topics (Reimer, Weinkauf,

**Table 2. Description of Issues Used in the Factor Analysis**

| Issue | Description | Mean | Std. Dev. | Loading |
|---|---|---|---|---|
| Factor 1: environment- and energy-oriented attitude | | | | |
| 1 | I am concerned with how much fuel I use for farming. | 2.837 | 0.643 | 0.424 |
| 2 | I would be willing to use a bio-based fuel. | 3.008 | 0.703 | 0.363 |
| 3 | Chemical carry over is a concern for me. | 3.151 | 0.678 | 0.564 |
| 4 | Reducing soil erosion makes economic sense for my farm. | 3.454 | 0.539 | 0.707 |
| 5 | Farmers have responsibility to use farm practices known to cause minimal soil erosion. | 3.144 | 0.602 | 0.468 |
| Factor 2: conservation-priority attitude | | | | |
| 6 | Receiving a conservation award is worth a great deal and can compensate for lower profits | 2.213 | 0.721 | 0.982 |
| Factor 3: profit-oriented attitude | | | | |
| 7 | Technical advances in seeds, fertilizers, and pesticides can offset the adverse effects of soil erosion on productivity. | 2.659 | 0.818 | 0.292 |
| 8 | A farmer's priority task should be profit maximization. | 2.525 | 0.705 | 0.615 |
| 9 | Maximizing profits this year is more important than maintaining cropland productivity in the future. | 1.994 | 0.659 | 0.633 |

and Prokopy, 2012; Floress et al., 2017). Factor analysis, which reduces dimensionality based on intercorrelations among variables, has been used to group farmer attitudinal variables into fewer latent factors (Kessler, 2006; Thompson, Reimer, and Prokopy, 2015; Syan et al., 2019).

Incentive payments can also affect farmers' perceived profitability and adoption decisions (Bowman and Lynch, 2019; Sustainable Agriculture Research and Education, 2019). In addition to federal program incentives, farmers can sometimes obtain additional incentives through state programs or conservation agencies. To capture the potential effect of subsidy on farmers' perceived profitability and future adoption decisions, we inquired whether adopters received cost shares to offset their cover-crop adoption expenses. Of 292 cover-crop adopters who answered the cost-share question, 45, 38, 18, and 14 producers received subsidies of "< 10%," "10%–20%," "20%–30%," and ">30%," respectively, while 177 (61%) reported that they receive no subsidy. According to McCann and Claassen (2016), the complexity of conservation programs and onerous application procedures could discourage farmers from participating in USDA conservation programs such as the Environment Quality Incentive Program (EQIP) and the Conservation Stewardship Program (CSP).

Our study region is located in a climate transition zone that exhibits a distinct east–west declining average precipitation, which could result in heterogeneous cover-crop performance. For example, cover crops facilitate successful planting by absorbing excessive soil moisture in mesic regions, but they can reduce crop yields in semi-arid regions (Robinson and Nielsen, 2015; U.S. Department of Agriculture, 2019). To capture the potential weather effect, we included 30-year average precipitation data from May to September at the county-average level, from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM). As indicated in Table 1, average precipitation ranges from 13.279 to 19.359 inches, which reflects considerable disparities across the study region.

## Empirical Model

### *Factor Analysis*

Factor analysis is a statistical method that groups variables based on their correlations into a few unobservable variables, called factors (Johnson and Wichern, 2007). We adopted the orthogonal factor model (OFM). Each of the $p$ attitudinal variables (i.e., $X_i$ $(1 \leq i \leq p)$) was modeled as a linear combination of $m$ factors (i.e., $X_i - \mu_i = l_{i1}F_1 + l_{i2}F_2 + \ldots + l_{im}F_m + e_i$), where $\mu_i$ is the mean of attitudinal variable $i$. The unobservable factors are denoted by $F_1, F_2, \ldots, F_m$; $l_{ij}$ $(1 \leq i \leq p, 1 \leq j \leq m)$ is the loading of $F_j$ on $X_i$ (Johnson and Wichern, 2007), and $e_i$ is the $i$th specific effect. As a standard model specification for factor analysis, OFM assumes each factor to be orthogonal to the other factors, with 0 mean and unit variance (i.e., ) (Johnson and Wichern, 2007).

We used the maximum likelihood estimation method to estimate factors $F_i$ and the likelihood ratio test (LRT) to determine the number of factors (Johnson and Wichern, 2007). If LRT indicates the insufficiency of n factors ($n \geq 1$), then we would conduct the LRT test for the sufficiency of $n+1$ factors. We repeated this process until LRT tests showed the current number of factors to be sufficient to determine the optimal number of factors for our study (Johnson and Wichern, 2007). These factors were then used as explanatory variables in our bivariate ordinal regression analysis.

*Bivariate Ordered Logit Model*

Since the dependent variables for both perceived cover-crop profitability and future likelihood of cover-crop adoption are ordinal, we used ordinal regression for the analysis (Agresti, 2010; Bilder and Loughin, 2014). In addition, these two variables could potentially correlate such that farmers who perceive higher profitability in cover crops are also more likely to adopt the practice in the future, warranting the use of a bivariate ordered logit model (Hirk, Hornik, and Vana, 2019). In this regard, previous literature has utilized similar bivariate or multivariate models to jointly analyze potentially related dependent variables (Adusumilli and Wang, 2018; Mutale, Kalinda, and Kuntashula, 2017; Wang et al., 2019a).

Let $Y_{ij}$ and $Y_{ij}^*$ denote farmer $i$'s observed and latent responses respectively, where $j=1$ stands for perceived profitability change and $j=2$ stands for future adoption likelihood. The response variables can take $K$ levels with $K \geq 2$. For each level k $(1 \leq \mathrm{k} \leq K)$, the relationship between $Y_{ij}$ and $Y_{ij}^*$ is described as:

$$Y_{ij} = k \text{ } if \text{ } \delta_{k-1,\, j} < Y_{ij}^* \leq \delta_{k,\, j}, \tag{1}$$

where the unobservable threshold parameters for response $j$ $(j = 1,\ 2)$ satisfy the following condition: $-\infty = \delta_{0,j} < \delta_{1,j} < \delta_{2,j} < \cdots < \delta_{K,j} = \infty$. In our context, both profitability change and future adoption likelihood take three levels, with $K = 3$.

A multivariate linear regression model is used for latent vector $Y_i^* = (Y_{i1}^*, Y_{i2}^*)^T$ (Johnson and Wichern, 2007; Hirk, Hornik, and Vana, 2018, 2019) and can be represented as follows:

$$Y_{i1}^* = \beta_{10} + x_{i1}^T \beta_1 + \varepsilon_{i1}; \tag{2}$$

$$Y_{i2}^* = \beta_{20} + x_{i2}^T \beta_2 + \varepsilon_{i2}; \tag{3}$$

where $\beta_{j0}$ $(j = 1,\ 2)$ are the intercept terms and $\beta_j = \left(\beta_{j1}, \ldots, \beta_{jP}\right)^T$ is the vector of regression coefficients. The error vector follows a bivariate logistic distribution with 0 mean and covariance matrix $\Sigma$ (i.e., $(\varepsilon_{i1}, \varepsilon_{i2})^T \sim Logistic\,(0, \Sigma)$) (Gumbel, 1961; Hirk, Hornik, and Vana, 2018).

We conducted the bivariate ordinal regression analysis using R software package "mvord" including maximum likelihood estimation (MLE) and statistical inferences (Hirk, Hornik, and Vana, 2018). Due to the invariance property of MLE, the odds ratio of response $j$ with respect to explanatory variable $q$ $(1 \leq \mathrm{q} \leq P)$ can be estimated as $\exp(\hat{\beta}_{jq})$, where $\hat{\beta}_{jq}$ is the MLE estimated value of $\beta_{jq}$. The statistical tests on coefficient and the corresponding odds ratio are equivalent, and the significance levels for these two values are the same.

**Table 3. Current Cover-Crop Usage Status Based on 2018 South Dakota Farmer Survey**

| Cover-Crop Usage | No. of Producers | Percentage of Producers (%) | Average Percentage of Land That Uses Cover Crops (%) |
|---|---|---|---|
| Never used | 350 | 51.3 | 0 |
| <3 years | 148 | 21.7 | 12 |
| 3–5 years | 74 | 10.9 | 22 |
| 6–10 years | 52 | 7.6 | 31 |
| >10 years | 43 | 6.3 | 45 |
| Discontinued | 15 | 2.2 | 5[a] |
| Total | 682 | 100 | 13 |

*Notes:* [a] For farmers who discontinued cover crop, we asked about the average percentage of land that had been planted for cover crops in the past.

## Results and Discussion

### *General Statistics Description*

Table 3 describes current cover-crop usage in this transition zone. The percentage of producers in different categories indicate that cover-crop usage in South Dakota increased from 13.9% in 2012 to 46.5% in 2017. This increasing trend is also reflected by the state average data. Overall, there were 1,369 and 2,154 cover-crop users in South Dakota in 2012 and 2017, respectively, accounting for 6.4% and 10.3% of total crop operations for the respective years (U.S. Department of Agriculture, 2017a). This indicates that despite the growth in statewide cover-crop adoption rate, the average percentage of cover-crop users was much lower than our survey findings would suggest. According to Groves, Presser, and Dipko (2004), the higher adoption rate could be attributable to the higher likelihood of participation among those who are interested in the survey versus those who are not interested. Such participation bias issues could exist in other survey studies as well. For example, recent convenience sample survey conducted by the Conservation Technology Information Center (2017) reported that 88% respondents across the United States used cover crops in 2016. A survey of Nebraska producers found that 87% of 82 respondents managed cover crops on their farms (Oliveira, Butts, and Werle, 2019). In our context, this means that farmers interested in adopting conservation practices are more likely to respond. In addition, small farms are underrepresented in our sample relative to the census data. Farm size has been shown to be positively related to conservation practice adoption (Prokopy et al., 2019), which also helps to explain the higher cover-crop adoption rate in our survey relative to the state average. Therefore, caution is required when interpreting survey results since the cover-crop users are likely overrepresented among the survey respondents.

Another trend that becomes apparent is that those who used cover crops for more years have also adopted cover crops on a higher percentage of the land they farm (Table 3). Yet those who discontinued only used cover crops on 5% of their land before their decision to discontinue. This implies a gradual adoption process and that producers tend to start using cover crops by experimenting with them on a small percentage of their land before deciding whether to expand or discontinue the practice. In this regard, our finding is consistent with Pannell et al. (2006), who found that the use of conservation practices may be scaled up based on farmers' evaluation of trial results. In most cases, farmers' adoption of the conservation practices is partial and stepwise, which may be attributed to heterogeneous economic performance in different circumstances (Pannell, Llewellyn, and Corbeels, 2014). Dunn et al. (2016) similarly found that continuous use among early adopters of cover crops is associated with a willingness to self-learn and trial and error.

Table 4 reports the perceived change in cover-crop profitability among producers from different user groups. Overall, 62.6% reported no major change (within 5%) in profitability after cover-crop adoption, 21.7% indicated their profits increased by more than 5%, and 15.7% perceived that

**Table 4. Perceived Change in Cover-Crop Profitability by Current Usage Status Based on 2018 South Dakota Farmer Survey**

| Cover-Crop Usage | Reduced by More Than 5% | Very Little Change (within 5%) | Increased by More Than 5% |
|---|---|---|---|
| Never used | 56 | 194 | 46 |
| | (19.6) | (64.3) | (16.1) |
| <3 years | 16 | 88 | 27 |
| | (12.2) | (67.2) | (20.6) |
| 3–5 years | 10 | 40 | 20 |
| | (14.3) | (57.1) | (28.6) |
| 6–10 years | 5 | 28 | 18 |
| | (9.8) | (54.9) | (35.3) |
| >10 years | 5 | 20 | 17 |
| | (11.9) | (47.6) | (40.5) |
| Discontinued | 1 | 10 | 0 |
| | (9.1) | (90.9) | (0.0) |
| Total | 93 | 370 | 128 |
| | (15.7) | (62.6) | (21.7) |

*Notes:* Numbers in parentheses are percentage of farmers for each cover-crop usage category who perceived change.

their profits decreased by more than 5%. It is noticeable that for all cover-crop usage groups, the majority of producers believe cover crops have generated very little change in profit. However, we can see that the duration of cover-crop usage is positively associated with actual or perceived change in profitability. For example, only 20.6% of farmers who practiced for fewer than 3 years perceived a more than 5% increase in profitability, while 40.5% of their counterparts in the >10 years group perceived a more than 5% increase in profitability. Not surprisingly, no one who discontinued the practice experienced an increase in profitability. Note that Table 4 results may not necessarily indicate a causal relationship between long-term usage and high profitability, as both variables are likely contingent on idiosyncratic farmer and farm characteristics. In this regard, on-farm experimental studies that control for factors such as management and soil and weather conditions can better explore the causal relationship between usage duration and economic benefit.

Table 5 displays intended cover-crop adoption in the future, grouped by current length of usage. Generally, the longer farmers have been using cover crops, the higher likelihood that they will continue using cover cops. For example, of those who have adopted for fewer than 3 years, fewer than 40% indicated they were very/extremely likely to adopt in the future, while for those who have adopted for 3–5 years, more than 60% indicated they were extremely likely to adopt in the future. For those who have adopted cover crops for more than 6 years, the stated adoption likelihood is approximately 80%. Compared with the adopters, those who have never used cover crops were much less likely to adopt it in the future, as only 5.5% of nonadopters indicated a very/extreme likelihood of adopting in the future. From Table 5, it can be inferred that approximately 80% of our survey respondents indicated a likelihood to adopt cover crops in the future: 50.5% selected "somewhat or moderately likely" to adopt and 29.7% indicating "very or extremely likely" to adopt. This implies many producers in South Dakota are considering—or at least not opposed to—adopting cover crops in the future. Therefore, dissemination of necessary information that addresses producers' concerns will likely to be effective in terms of increasing the cover-crop adoption rate.

**Table 5. Producers' Likelihood of Using Cover Crops in the Future by Current Usage Status Based on 2018 South Dakota Farmer Survey**

| Cover-Crop Usage | Reduced by More Than 5% | Very Little Change (within 5%) | Increased by More Than 5% |
|---|---|---|---|
| Never used | 116 | 208 | 19 |
| | (33.8) | (60.6) | (5.5) |
| <3 years | 12 | 78 | 55 |
| | (8.3) | (53.8) | (37.9) |
| 3–5 years | 1 | 25 | 45 |
| | (1.4) | (35.2) | (63.4) |
| 6–10 years | 0 | 9 | 42 |
| | (0.0) | (17.6) | (82.4) |
| >10 years | 2 | 7 | 34 |
| | (4.7) | (16.3) | (79.1) |
| Discontinued | 1 | 10 | 3 |
| | (7.1) | (71.4) | (21.4) |
| Total | 132 | 337 | 198 |
| | (19.8) | (50.5) | (29.7) |

*Notes:* Numbers in parentheses are percentage of farmers for each cover-crop usage category who indicated future usage likelihood.

### *Factor Analysis*

Based on the aforementioned LRT procedure, we determined three factors to be sufficient. These factors were constructed from the nine attitudinal variables and their loading factors (Table 2). Factor 1 can be categorized as farmers' environment-oriented attitude, which contains five items: "concern with fuel usage amount," "willingness to use bio-based fuel," "concern with chemical carry over," "economic benefit of soil erosion reduction," and "farmers' responsibility to take measures in reducing soil erosion." In general, farmers' ratings in this category were above 3, which indicated their agreement with these issues. In particular, farmers showed most agreement with the statement that soil health made economic sense for their farm. Factor 2 only contains one variable: "prioritization of conservation award over profits," which categorized farmers' conservation-priority attitude and received an average rating of 2.213, implying disagreement among the majority of farmers. Factor 3 contains three items categorizing farmers' profit-oriented attitude: "technology can offset soil erosion consequences," "farmer's priority on profit maximization," and "the importance of short-term profit maximization," all of which received ratings below 3. A comparison of these three factors suggested to us that most survey respondents demonstrated environment- and energy-oriented attitudes (Factor 1) and did not view short-term profit maximization as their top priority (Factor 3). However, they generally disagreed with the statement in Factor 2 that receiving conservation awards could compensate for reduced profits, which implied their dual preference toward environmental and long-term economic benefits.

### *Bivariate Ordered Logit Model Estimation*

Table 6 presents the model estimation results for perceived cover-crop profitability and future likelihood of cover-crop adoption, referred to as Models I and II, respectively. The correlation

**Table 6. Bivariate Ordered Logit Model Estimates for Perceived Cover-Crop Profitability and Future Likelihood of Cover-Crop Adoption ($N = 406$)**

| Independent Variable | Coeff. Est. | Std. Err. | Odds Ratio | Coeff. Est. | Std. Err. | Odds Ratio |
|---|---|---|---|---|---|---|
| Years of cover-crop usage | 0.227** | 0.109 | 1.255** | 1.051*** | 0.121 | 2.860*** |
| Conservation-tillage adoption | −0.174 | 0.296 | 0.841 | 0.449 | 0.301 | 1.566 |
| Diversity rotation (3+ crops) | 0.347 | 0.298 | 1.415 | 0.055 | 0.334 | 1.057 |
| Grazing potential | 0.063 | 0.270 | 1.065 | 0.940*** | 0.297 | 2.561*** |
| Decision making years | 0.003 | 0.009 | 1.003 | −0.020** | 0.009 | 0.980** |
| Gender | 1.111 | 0.978 | 3.038 | 1.866* | 1.056 | 6.464* |
| Education (high school) | −0.180 | 0.775 | 0.835 | −0.830 | 0.868 | 0.436 |
| Education (some college) | 0.159 | 0.771 | 1.172 | −0.493 | 0.850 | 0.611 |
| Education (college degree) | −0.119 | 0.839 | 0.888 | −1.054 | 0.924 | 0.349 |
| Education (postgraduate degree) | 0.226 | 1.041 | 1.254 | −0.446 | 1.081 | 0.640 |
| Ag major/minor | 0.046 | 0.462 | 1.047 | 0.551 | 0.472 | 1.736 |
| University Extension | 0.313* | 0.179 | 1.368* | 0.242 | 0.196 | 1.274 |
| Social networks | 0.343* | 0.194 | 1.409* | 0.296 | 0.192 | 1.345 |
| Gross sales ($50,000–$99,999) | 0.395 | 0.471 | 1.485 | 0.327 | 0.425 | 1.387 |
| Gross sales ($100,000–$249,999) | −0.324 | 0.436 | 0.723 | 0.754* | 0.437 | 2.127* |
| Gross sales ($250,000–$499,999) | 0.190 | 0.428 | 1.209 | 0.886** | 0.426 | 2.426** |
| Gross sales ($500,000–$999,999) | −0.194 | 0.465 | 0.824 | 0.805* | 0.438 | 2.237* |
| Gross sales ($1 million or more) | −0.360 | 0.498 | 0.697 | 0.542 | 0.517 | 1.719 |
| F1: environ. and energy-oriented | 0.007 | 0.154 | 1.007 | 0.358** | 0.161 | 1.431** |
| F2: conservation priority | −0.107 | 0.127 | 0.898 | −0.198 | 0.133 | 0.820 |
| F3: profit-oriented | 0.038 | 0.168 | 1.039 | −0.447*** | 0.173 | 0.640*** |
| Cost share received | 0.163 | 0.170 | 1.178 | 0.214 | 0.165 | 1.238 |
| Precipitation | 0.119 | 0.080 | 1.127 | −0.046 | 0.092 | 0.955 |
| $\rho$ | 0.352*** | 0.082 | n/a | | | |
| Log-likelihood | −626.8 | | | | | |
| Prob > $\chi^2$ | 0.0000 | | | | | |

*Notes:* Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. F1, F2, and F3 represent Factors 1–3, respectively, and n/a indicates "not applicable."

coefficient ($\rho$) between the bivariate outcomes is 0.352 ($p < 0.01$), which justifies modeling the two dependent variables simultaneously in a bivariate logit model. In Table 6, we report the estimated coefficient, corresponding standard error, and odds ratio for each explanatory variable. Due to the invariance property of MLE, each coefficient and its corresponding odds ratio share the same *p*-value. The odds ratio for Model I can be interpreted as the change in the predicted odds of perceived profitability in the increased category versus the nonincreased category,[4] given a 1-unit increase in the corresponding variable while keeping other variables unchanged. The odds ratio in Model II can be interpreted in the similar manner.

Based on the Model I findings, there is a significantly greater likelihood of perceived increase in profitability for those who used cover crops for a longer period. *Ceteris paribus*, for every 1-unit increase in cover-crop usage years, the odds of perceived increased versus nonincreased profitability is 1.255 times greater (i.e., a farmer is 1.255 times more likely than not to perceive that cover-crop profitability increased given a 1-unit increase in usage years). Even though no causal relationship between cover-crop usage duration and increased profitability can be inferred from our modeling results, our finding shows consistency with experimental research findings. For example,

[4] We assume that the odds of $Y_1$ in the greater than 5% ($Y_1 = 3$) versus not greater than 5% ($Y_1 = 1,2$) category and the odds of $Y_1$ in the no less than −5% ($Y_1 = 2,3$) versus less than −5% category ($Y_1 = 1$) are the same.

the soil benefits of using cover crops, such as improvement in soil nitrogen and soil organic matter, accumulate over long-term of continuous use, which in return will contribute to cash crop yield and profitability increases (Mbuthia et al., 2015; Adusumilli and Fromme, 2016). In addition, through longer years of usage, farmers will have more experiences in choosing the seed mix, establishing, and terminating cover crops, which could further generate profitability increases through the effect of learning-by-doing.

According to the education types defined by Weir and Knight (2004), formal education—in our context, school education and agricultural-related degrees—has no significant role in perceived profitability and cover-crop adoption decisions. However, nonformal and informal education play significant roles on farmers' perceived cover-crop profitability. Specifically, for farmers who showed more agreement with attending Extension workshops and utilizing social networks to learn new innovative ideas, the odds of perceived increased versus nonincreased profitability are, respectively, 1.368 and 1.409 times greater. Proper cover-crop management, contingent on the soil and climatic conditions in farmers' local regions, is essential to achieving economic benefits (Challandes, 2019). According to Pannell et al. (2006), adoption is a learning process that involves improvement in farmers' knowledge and skills to apply the practice on their own farms. Therefore, the factors that potentially accelerate farmers' learning progress, such as Extension training workshops and social networks, could facilitate the adoption process and play a positive role in perceived profitability.

Model II presents the estimation results for the likelihood of cover-crop usage in the future. Like the result in Model I, we found that the duration of cover-crop usage was positively associated with future likelihood of cover-crop adoption. Specifically, 1-unit increase in cover-crop usage duration is associated with the farmers' odds of future adoption being 2.860 times greater. This intuitively makes sense, as a longer adoption period could indicate stronger commitment to cover-crop usage, which in return leads to a higher likelihood of adoption in the future. In addition, we found that for farmers who could utilize cover crops for grazing, the odds of likely future adoption were 2.561 times greater than non-adoption. These results were attributed to additional revenue from the cattle enterprises.

Model II also indicates that the length of decision-making years has a negative effect on future adoption decisions. Specially, as decision-making duration increases by 1 year, the odds of adopting cover crops in the future are 0.980 times less likely. This suggest that as farmers age, their motivation to adopt new practices decreases. In this regard, O'Connell et al. (2015) found that although farmers with more than 10 years of farm management experience had greater levels of cover-crop implementation, farmers with fewer than 3 years of experience were more likely to agree with the benefits of cover crops and were less likely to view residue incorporation as a challenge. However, not all studies find that farm management experience impedes adoption. Bergtold et al. (2012) estimated that more experienced and older farmers were more likely to adopt winter cover crops. Gender also plays a significant role in terms of future likelihood of adoption. The odds ratio of 6.464 indicates that compared to men, women are more likely than to adopt cover crops in the future. This finding is consistent with the findings of Druschke and Secchi (2014), who found that women are more likely to have positive attitudes toward conservation practices than men.

Farm scale, as measured by gross sales value, has a nonlinear effect on cover-crop adoption decisions. Specifically, compared with farms with gross sales of <$50,000, the odds of likely future adoption versus nonadoption are 2.127, 2.426, and 2.237 times greater for farms with gross sales of $100,000–$249,999, $250,000–$499,999, and $500,000–$999,999, respectively. However, farms with gross sales of $50,000–$99,999 and ≥$1 million are not significantly different from those with <$50,000 regarding future adoption decisions. This indicates that, relative to small farms of <$100,000 and very large farms of ≥$1 million, medium and large farms with gross sales of $100,000–$99,999 are more likely to adopt cover crops. Our results are consistent with those of Lee and McCann (2019), who found that the farm size effect is not linear. On one hand, it has been shown that larger farms tend to have higher rates of adoption of soil conservation and best management practices (Neill and Lee, 1999; Habron, 2004). One frequently suggested explanation is that larger farm size allows farmers to spread the fixed capital and information acquisition costs associated with the adoption of new technologies across more acres. On the other hand, cover-crop implementation implies additional time and labor costs, which could become extremely burdensome for very large farms (Conservation Technology Information Center, 2017), which could explain why these farms are less likely than medium and large farms to adopt cover crops.

Several studies have showed that farmers' subjective beliefs, such as perceptions of soil health importance and economic benefits of soil health practices, play important roles in conservation practice adoption (Singer, Nusser, and Alf, 2007; Bergtold et al., 2012; Reimer and Prokopy, 2014; Wang et al., 2019a). Similarly, we found that the factors reflecting farmers' environment- and energy-oriented attitudes and profit-oriented attitudes are significant in affecting cover-crop adoption decisions (Table 6). The odds of future adoption are 1.431 times greater when farmers expressed greater concerns toward environment-related issues. However, the odds of future adoption decrease to 0.640 when farmers emphasized short-term profitability. This is consistent with previous literature findings that farmers' emphasis on soil health and attributes of the new practice tend to positively influence adoption decisions, while farmers who need more monetary incentives to adopt such practices are less likely to adopt (Adesina and Baidu-Forson, 1995; Ryan, Erickson, and De Young, 2003; Singer, Nusser, and Alf, 2007; Bergtold et al., 2012; Reimer and Prokopy, 2014; Wang et al., 2019a). Our findings emphasize the necessity of helping farmers better understand the long-term environmental and economic consequences of different agricultural practices so that they can make more informed decisions.

We found that higher amounts of precipitation lead to increased perceived profitability for cover crops. However, this effect is not significant at the 10% level in this study ($p = 0.14$). The lack of significance might be due to the relatively low deviation in precipitation across our study region. Lee and McCann (2019) utilized multistate survey data with higher precipitation variance across the study region and found precipitation to be a significant factor in cover-crop adoption decisions. Similarly, cost share received to offset initial cover-crop expenses plays no significant role, implying that those who receive cost share did not indicate higher perceived profitability than those who self-funded cover-crop expenses. Previous literature has found conflicting results regarding this issue. For example, Lee and McCann found that farmers who received higher amount of cost share were more likely to adopt cover crops. Bergtold et al. (2012), however, found that cost share assistance received as a result of cover cropping reduced the perceived yield benefit from the following cash crop, as only one-third of farmers who received cost shares perceived a positive change in yield. A plausible explanation for such a counterintuitive finding is that most cost-share recipients perceived a low benefit from cover-crop usage and would not have adopted them without cost share, as confirmed by extremely high additionality level for cover crops at 97.6% (Fleming, Lichtenberg, and Newburn, 2018). In contrast, those who self-funded cover-crop expenses are likely to perceive sufficiently high profits, so that they would adopt even without cost share.

A comparison of Model I and II results indicates that cover-crop adoption may not hinge on perceived profits. For example, operators of medium and large farms, though not perceiving significantly higher cover-crop profitability than those operating small and very large farms, are more likely to adopt cover crops in the future. This is also true for more environment- and energy-oriented producers. This implies that for many producers, the motivations for cover-crop adoption are not merely economic. The Conservation Technology Information Center (2017) drew similar conclusions: Adopters identified soil health as the top outcome of cover-crop usage, followed by yield and weed control benefits. Plastina et al. (2020) also reported that despite evidence that cover crops reduced farm profitability in 2014/15 for most farmers, they continued to use cover crops due to perceived long-term benefits.

## Conclusion

This paper examined factors that affect the perceived economic effects and future adoption or continued usage of cover crops. We also analyzed how farmers' perceptions of changes in profitability and future likelihood of adoption vary across short- and long-term adopters and nonadopters. We found that while only 16.1% of producers were cover-crop users as of 2013, nearly half of producers claimed to be nonusers as of 2018. With 50.5% of producers indicating a moderate desire and 29.7% indicating an extreme desire for future adoption, the cover-crop adoption rate will likely continue to grow. Even though our results are based on farmer survey responses from east and central South Dakota, we observe similar findings in recent cover-crop studies from other U.S. regions. Therefore, out results and policy implications can be tested and generalized in other regions, especially the Northern Great Plains.

Our results demonstrated that longer-term adopters are more likely to perceive a profitability increase and to continue planting cover crops in the future. This is consistent with experimental findings that cover-crop benefits accumulate over the long term and require sufficient time for soil health to improve and profitability to increase. The positive roles played by cover-crop usage years could be attributed to both soil health improvement and the learning-by-doing effect. As shown by Dunn et al. (2016), continuous use of cover crops is associated with a willingness to self-learn and experiment through trial and error. Results from our study also indicate that learning processes facilitated by university Extension and social networks will likely boost farmers' perceptions of cover-crop profitability.

Results presented in this study could provide insights regarding future Extension and research priorities. For example, our findings indicate that farm management and demographic characteristics may affect future adoption plans for cover crops. Specially, producers operating medium and large farms and with less experience are more likely to adopt cover crops in the future, as are female operators. Therefore, outreach effort targeting these groups could be more effective in improving cover-crop adoption rates. In addition, we found that farmers with the potential to integrate livestock into their cropping system are more likely to adopt cover crops, which suggests complementary roles of different soil conservation practices. Thus, cover crops can be more efficiently promoted among producers with livestock grazing potential.

Moreover, future cover-crop adoption decisions are positively affected by environment-and energy-oriented attitudes but negatively affected by an emphasis on short-term economic profit in general. These findings suggest that to help improve future cover-crop adoption rates, more efforts can be directed toward educational programs aimed at enhancing understanding of how cover crops can affect soil health and economic profit in both short- and long-terms. Further, this study provides insights on how the economic returns to cover crops in the trial years may affect future adoption. We found that while farmers' future adoption decisions may not solely hinge on the perceive profitability, lack of profitability could be a plausible reason for discontinuation, as all farmers who discontinued usage perceived no increase in profitability. This suggests that future working land programs should consider not only the optimal cost share amount but also the optimal length of subsidy provided to new adopters on a regional basis, to ensure that program participants continue using cover crops even after the program expires, thereby increasing the retention rate of new cover-crop adopters.

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# Appendix A

## Table A1. Correlation Matrix of Attitudinal Variables Used for Factor Analysis

| | Issue 1 | Issue 2 | Issue 3 | Issue 4 | Issue 5 | Issue 6 | Issue 7 | Issue 8 | Issue 9 |
|---|---|---|---|---|---|---|---|---|---|
| Issue 1 | 1.000*** | | | | | | | | |
| Issue 2 | 0.198*** | 1.000*** | | | | | | | |
| Issue 3 | 0.331*** | 0.200*** | 1.000*** | | | | | | |
| Issue 4 | 0.238*** | 0.255*** | 0.392*** | 1.000*** | | | | | |
| Issue 5 | 0.180*** | 0.146*** | 0.203*** | 0.366*** | 1.000*** | | | | |
| Issue 6 | 0.125*** | 0.071 | 0.101** | −0.018 | 0.199*** | 1.000*** | | | |
| Issue 7 | 0.117** | 0.009 | 0.093** | 0.009 | 0.053 | 0.184*** | 1.000*** | | |
| Issue 8 | 0.111** | 0.033 | 0.062 | 0.039 | 0.028 | 0.022 | 0.180*** | 1.000*** | |
| Issue 9 | 0.052 | −0.027 | −0.021 | −0.098** | −0.072 | 0.144*** | 0.175*** | 0.382*** | 1.000*** |

*Notes:* Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level, respectively. Table 2 describes issues 1–9.