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Factors Affecting the Farmers’ Adoption Decision and Usage Intensity of Conservation Tillage in Eastern South Dakota

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FACTORS AFFECTING THE FARMERS' ADOPTION DECISION AND USAGE INTENSITY OF CONSERVATION TILLAGE IN EASTERN SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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This thesis is dedicated to my family, especially to my grandmother, who is a constant source of motivation for me, and their unending love and support in my life.

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ABBREVIATIONS

CST = Conservation Tillage

CT = Conventional Tillage

NT = No-Till

RT = Reduced Tillage

SDSU = South Dakota State University

US = United States

USDA = United States Department of Agriculture

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ABSTRACT

FACTORS AFFECTING THE FARMERS' ADOPTION DECISION AND USAGE INTENSITY OF CONSERVATION TILLAGE IN EASTERN SOUTH DAKOTA

SARMILA BELBASE

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Many farmers are continuously looking for new ways to protect soil and increase yields and returns on investment. No-tillage and reduced-tillage farming may provide ways to achieve these goals. Such practices have been found as the alternative to overcoming the environmental challenge posed by conventional tillage practice and providing significant economic returns. However, a comprehensive study of the factors affecting the adoption and adoption intensity of these practices is lacking. This paper intends to fill this gap by utilizing a double hurdle model to analyze farmer survey data. The data used in this study were obtained from a survey of 350 commodity crop producers about their land management practices and attitudes in the eastern part of South Dakota. Our findings indicated that determinants affecting the adoption decision and intensity of adoption are mostly different. In addition to this, factors affecting no-tillage and reduced tillage adoption are also mostly different. Our findings indicated that farmers were more likely to practice no-till to control soil erosion, improve soil quality, increase yield, and earn profit from farming. Similarly, farmers involved in decision-making years for a longer period had positive influence on the adoption of reduced tillage. We found that: 1) farm size as a common factor affecting no-tillage and reduced tillage adoption and 2) that distance from home to field and rainfall had a positive and a negative impact on reduced tillage and no-till adoption respectively. Similarly, our results suggest that farmers who have high erodible land are more likely to expand no-till acres. As a result, outreach efforts aimed towards these populations may be more successful in increasing the percentage of no-till acres adoption.

Keywords: No-tillage, Adoption, Adoption Intensity, Farmers, Reduced Tillage, Survey data, South Dakota

INTRODUCTION

Since the 1930's, farmland soil erosion has been recognized as a serious concern in the United States (Uri, 1999). It removes the most productive surface soil which reduces soil productivity. Erosion has been identified as an important issue by the National Resource Conservation Service (NRCS), The American Farmland Trust (2018) and Fox and Johnson (2018). Studying soil conservation choices like conservation tillage is crucial since soils continue to experience substantial deterioration and loss under existing management techniques (Ogieriakhi and Woodward, 2022). Among soil conservation practices, conservation tillage (CST) is widely adopted all over the world. It entails planting crops directly into the ground without extensive soil preparation (Bolliger et al., 2006). The Conservation Technology Information Center (2002) defines conservation tillage as a system that covers at least 30% of the soil surface with residues. Different forms under CST like no-till, strip tillage, mulch tillage, and reduced tillage (most often considered as CST). This paper focuses on the adoption of conservation tillage in their farming practices. One of the conservation strategies developed to decrease soil erosion is no-till (Triplett and Dick, 2008). No-till also referred to as zero tillage is the practice in which soil is left undisturbed from sowing to the harvest and more than 30% of crop residues are left on soil which adequately protects the soil from erosion, provides significant economic returns, and gives enhances environmental benefits (Islam and Reeder, 2014). It was found that switching to NT and keeping residues resulted in an 87% decrease in soil erosion when compared to CT (Schuller et al., 2007). Van Doren et al. (1984) noted that soil loss was 90% less than expected when soil is not tilled for more than 1 year. Similarly, reduced tillage can be defined as full-width tillage that involves one or more tillage operations that disturb the entire soil surface, which is performed before or during planting, and there is a 15 to 30% residue cover (The Conservation Technology Information Center, 2002).

Lal (2006) suggested that with the adoption of improved conservation practices (such as the use of no-till and crop residue), food security can be achieved along with a reduction in environmental pollution. Several works of literature emphasized the importance of the no-till in the farming system (Lal, 2006; Triplett and Dick, 2008; Huggins and Reganold, 2008; Mathew et al., 2012; Islam and Reeder, 2014). For example, Triplett and Dick (2008) found that no-till helps to eliminate soil erosion, improve soil health, and increases the store of organic nutrients in the soil. Similarly, no-till improves water quality as well by preventing chemical leaching losses (Kanwar et al., 1997) Similarly, many studies found that adoption of no-till improved yield and system productivity (Das et al,2014; Gosh et al.,2015; Parihar et al.,2018). Studies found that no-till helps in economic benefits through a decrease in the cost of production, labor, and fuel such as addressed that with the use of no-till labor input decreases from 3 hours to 1 hour while there is a 70% decrease in fuel consumption (Lankoski et al., 2004; Creech, 2017). For example, the inclusion of no-till in wheat farming increased from a gross margin of $84/ha compared to the conventional method due to a decrease in the operating costs and labor costs under no-till (Rouabhi et al.,2019).

As of 2007, no-till was only adopted in one-third of the total cropland in the US (Larson et al.,2010). Approximately, in 2009 35.5% of US cropland was under no-tillage (Horowitz et al.,2010). Between 2012 and 2017, the number of farms using intense tillage methods decreased by 35% and the number of acres decreased by 24% of total cropland in the US (USDA, 2017). Likewise, it also found that close to 35% of cropland in the United

States is now managed with reduced tillage, indicating that farmers are starting to embrace long-term investment. Similarly, in South Dakota, it was found that 7.7 million acres were under no-till adoption which was 52.4% of total cropland in 2017 which was increased by 7% since 2012 while reduced tillage was adopted on 29.4% of total cropland in the South Dakota (USDA, 2017). Also, cropland under conventional tillage decreased by 33.8% between 2012 and 2017 which comprises only 18.2% of the total cropped area (USDA, 2017). In USA, main crops like cotton, corn, wheat, and soybean were cropped which accounted for 225 million acres in 2010 and 242 million acres in 2011, and 39% of combined corn, wheat, cotton, and soybean acreage had adopted no-till completely in all parts of the field (Wade, Claassen and Wallander,2015). Continuous no-till is adopted on 21% of total cultivated cropland in the United States (Creech, 2017).

Several issues have been identified in previous studies as contributing to the limited adoption of no-till in the farming system. The potential factors include farmers' perception, confidence to take the risk, level of education, extension visit, farm size, field characteristics, profit, family size, and level of income (Hua et al.,2004; Huggins and Reganold, 2008; Hussain et al.,2010; Ntshangase,2018; Panel et al.,2006; Prokopy et al., 2008; Rouabhi et al.,2018; Sheikh, 2003). The major hindrance to its adoption is that no-till incurs a greater risk of crop failure and has lower net returns from farming than conventional agriculture (Huggins and Reganold, 2008). To reduce production cost and improve environmental sustainability, US farmers are increasingly inclined towards no-till, but the use of no-till in the field has brought root diseases and their pathogens causing root disease to get a favorable environment under no-till and increase its number with a reduction in tillage (Paulitz,2006). With the continuous use of herbicides in no-till soil, certain weeds develop resistance to herbicides and high weeding costs are potential challenges to no-till adoption (D'Emden, 2004). Farmers either must choose no-till with frequent use of herbicides or practice intensive tillage in their farming system. A key problem with no-till farming is the growing use of herbicides to manage weeds, which increases the danger of herbicide resistance. Similarly, field characteristics may also determine which types of tillage should be used. For example, farmers may use no-till on highly erodible land to reduce the chances of soil erosion (Prokopy et al., 2008).

We found most of the research is based on the determinants affecting the adoption of no-till conservation practices, but, to the best of our knowledge, little research has been conducted to determine the factors affecting usage intensity of no-till and reduced tillage which is critical to understand for expansion of cropland under conservation tillage. Also, most studies focus on the conservation tillage, but very few studies have been conducted to compare the adoption behavior of no-till and the reduced tillage separately. This research aims to close this gap in two ways. First, this work adds to the pool of scholarly research that has studied the various causes of social and economic issues that prevent farmers from using no-till and reduced tillage. Second, literature distinguishes between factors affecting adoption and the intensity of adoption is scarce (Awotide et al., 2014). Factors affecting the adoption of the practice and the percentage of land under the practice, or adoption intensity may or may not be the same, so these should be considered as two sequential decisions. Farmers first decide whether to adopt no-tillage/reduced tillage and then consider the extent of adoption under no-till/reduced tillage. However, most research is confined to finding the factors affecting adoption of conservation tillage (D’Souza, A., & Mishra, A. K., 2018, Uddin et al., 2017), neglecting the adoption intensity. Because after knowing the influencing factors of the adoption intensity then we can focus on those parameters for the expansion of conservation tillage. The main goal of introducing any sustainable practices is not only limited to adoption but how far the farmers take it, i.e on what percent of acres they adopt these practices. This paper goes beyond the determinants of no-till adoption to the intensity of adoption. Therefore, in response to these gaps, we tested the following hypotheses:

- Adoption and the intensity of adoption are processes affected by different factors.
- The factors affecting the probability of adoption and intensity of no-till and reduced tillage are mostly different.

RESEARCH OBJECTIVES

- To assess the adoption status of no-till and reduced tillage by using farmer-level data from South Dakota.
- To find the factors affecting the farmers' adoption decision and intensity of no-till and reduced tillage in South Dakota.
- To compare the determinants of farmers' adoption decision of reduced tillage with no-till.

LITERATURE REVIEW

CONSERVATION TILLAGE

Tillage practices influence the soil's physical, biological, and chemical properties, which in turn affect productivity and sustainability (Mathew et al., 2012). Farmers are practicing different tillage systems in their fields based on climatic conditions, soil characteristics and crop suitability (Reimer et al., 2012; Prokopy et al., 2008). In semiarid systems, no-till conserves water, therefore, favors no-till in their cropland whereas in humid and subhumid environments no-till is not suitable. Tillage includes no-till, conservation tillage, and conventional tillage. Planting directly into the residue of the previous crop without tillage that mixes or stirs the soil before planting is known as no-till (Paultiz, 2006). A no-till or no-tillage system is when a crop is planted straight into a seedbed that has not been prepared since the last seedbed (Kassam et al., 2009). No-till is either continuous or rotational no-till. Under continuous no-till, no-tillage that is practiced in a subsequent year is found to be more beneficial than rotational no-till (Triplett and Dick, 2008). Rotational no-till is defined as the no-till that is practiced alternately after tillage (Hill, 2001). Compared to continuous no-till, rotational no-till delay or prevent the improvements in soil physical and chemical properties like the formation of long-term macropore and increase organic matter in the soil because when a farmer rotates no-till with conventional tillage then short-term improvements in carbon stock are lost as only little amounts of residues are left on soil after harvest in conventional tillage (Hill,2001).

It is found that soil health properties at the 0 to 30 cm depth, such as soil microbial biomass (SMB), were distinctly improved under the innovative farming practices of continuous no-till (Islam and Reeder,2014). Also, sustainable agriculture is built on carbon-rich soils, which are eroded by conventional agricultural techniques (Thaler, 2021). Tillage that leaves less than 15% of the soil covered in crop leftovers after planting is referred to as conventional tillage (Horowitz, 2010) Similarly, conservation tillage is a tillage system in which at least 30% of crop residues are left in the field after harvest and play a significant role to reduce soil erosion (Uri,1999). In some studies, we found no-till, and minimum tillage or reduced tillage are under conservation tillage as each of these tillage methods has a very specific conservation objective, such as minimizing the amount of soil disturbed or maintaining surface residues to preserve soil, environmental, and economic viability (Archer, Im, Ransom, & Coley, 2017). To be precise, conservation tillage is a system that reduces the frequency and intensity of tillage practices. It includes different forms of tillage practices like reduced tillage, mulch tillage, ridge tillage, strip tillage, and so on.

Reduced tillage, also known as conservation tillage, involves leaving crop residue and stubble on the ground rather than removing them. Reduced tillage techniques can extend from decreasing the number of tillage passes to completely discontinuing tillage (zero tillage). It was found that farmers in the Midwest who lowered the amount of tilling saw higher yields of maize and soybeans as well as healthier soils and reduced production costs.(Horton, 2019).

FACTORS AFFECTING NO-TILL ADOPTION

No-till is not particularly new to agriculture. Adoption of no-till was slow even after the successful demonstration in 1950 but a change in farming techniques began to take its pace in the 1980s in the United States (Triplett and Dick, 2008). Conservation tillage techniques are used predominantly in the southeastern United States to conserve soil moisture, nutrients, and structure (Mathew et al., 2012). A review of the literature on no-till reveals several reasons for its lower adoption among farmers. There are several factors associated with which directly or indirectly drive farmers' adoption decision of no-till in their farming system. Several studies have been conducted to explain the determinants of no-till adoption. To get more insight into farmers' decision-making process, we need to focus on the overall factors that shape that decision. Therefore, all the observed factors are pooled into these categories as farm and farmers characteristics, and economic and environmental aspects of no-till farming.

FARMER AND FARM CHARACTERISTICS

The adoption of agricultural innovations differs from farmer to farmer, and researchers investigate the farmer and their farm characteristics to find the reason behind this unevenness (Ryan and Gross, 1943). Previous literature focused on the potential factors based on farmer and farm characteristics that affect the farmers' decision in the adoption process (Bavorova, Imamverdiyev & Ponkina, 2018; Samiee & Rezaei-Moghaddam, 2017; Bellotti, & Rochecouste, 2014; Westra and Olson, 1997; Caswell,2001; Wang et al.,2000; Antolini et al., 2015).

The number of years that a farmer is aware of another grower in their neighborhood who is practicing no-till has been demonstrated to have a positive impact on the adoption of no-till farming. Bavorova, Imamverdiyev & Ponkina (2018) pointed out that farmers are hesitant to adopt new technology, they are uncertain if it performs well in their production conditions as the reason for not using no-till. This also implies a low level of information among farmers about the technology and the economy involved in it. Samiee & Rezaei-Moghaddam (2017) also stated that given the lack of understanding that non-adopter farmers have about no-till technology, it is essential to educate them through lectures and workshops about the benefits of employing this innovation and how it functions. Farmers' social networks were found to be the most influencing factor in learning and making adoption decisions (Bellotti, & Rochecouste, 2014). Access to information, education, and training have also frequently been noted as influencing factors in the adoption of conservation tillage (Westra and Olson, 1997).

It is found that larger farms having higher cropping intensity are more likely to do an initial investment to adopt no-till as they have more potential to get benefits from the no-till (Caswell,2001; Wang et al.,2000) and large farms achieve economies of scale so are more likely to adopt any new technology (Antolini et al., 2015).

ECONOMIC ASPECTS

Farm income/profitability and labor sources are a few of the numerous elements that represent a farm's financial situation and operational management that have received some attention in studies of the adoption of conservation agriculture.

The adoptive farmers cited time savings and reduced costs as the key motivations for embracing no-till farming (Rouabhi et al., 2018). They also mentioned that subsidies are the major factors that motivate farmers to adopt and continue no-till farming. They found that the number of adopters decreased drastically but the average area under no-till increased. This is due to the completion of the subsidy program; the abundant farmers are unable to pursue no-till practice either for financial or technical reasons. In addition to this, Progress (2012) pointed out that once the subsidy program ended then farmers can no longer practice direct seeding.

Most of the research that was previously cited discovered that yields and different sorts of costs are affected by the tillage system that is used. Minimum- and no-tillage systems are typically found to have lower labor, fuel, maintenance, and equipment expenses than traditional tillage systems. Numerous studies indicate that the additional expense of herbicides in minimum- and zero-tillage systems outweigh the benefits. If the farmers can’t sense the profitability of certain new technology over the current one then they are reluctant to adopt it voluntarily (Bavorova, Imamverdiyev & Ponkina, 2018).

The reduced cost of production was found to be a significant driver for the adoption of zero-tillage and these cost-saving effects result in profitable farming (Erenstein,2012). However, reduced cost is not always observed as there is a weeding cost that is associated with zero-tillage. Wall (2007) stated that the farmers who use herbicides for weed control are more likely to achieve labor savings while less likely those who do it manually. Farmers with limited resources may not always be able to use herbicides because of local availability issues, cash flow issues, or a lack of farmer knowledge and training (Mazvimavi and Twomlow, 2009).

ENVIRONMENTAL ASPECTS

Caswell et al. (2001) found that high average annual rainfall was found to be highly significant and had a positive influence on adoption. Higher demand for crop residue as forage for livestock is also an impediment to the adoption of no-till (Triplett and Dick,2008). The soil and climatic factors influence the yield and ultimately affect the adoption of the practice by the farmers (Toliver et al., 2012). It was found that no-till produces greater mean yield than the tillage when crops were grown on loamy soils whereas there was yield risk when grown on sandy soil. A warm and humid climate with warmer soil favors no-tillage farming (Toliver et al., 2012). He also studied that the longer the no-till is practiced the higher will be the probability of having lower corn yield as compared to the tillage corn due to the residue that harbors insects, disease, and weeds infestation. To oppose this, Grabski and Desborough (2009) reported that in the first four years, soybean yield in CST was lower than in CT, but in the ten years that followed, CST outperformed CT in terms of yield. There is no discernible difference between CT and

CST's long-term crop yields, according to Boselli et al. (2020). Differences in the findings are due to the climate of the farming region (Toliver et al., 2012).

PERCEPTION AND ATTITUDES

The literature constantly highlights the importance of perceptions of the impact of CST adoption on short- and long-term returns to farming as a critical element that impacts farmers' willingness to adopt (Ogieriakhi and Woodward, 2022). D'Emden (2008) stated that the farmers' perception of the degree of their land susceptibility to soil erosion was found to be insignificant in the no-till adoption decision-making process. Similarly, many farmers think that switching from conventional to conservation tillage will result in a rise in weeds and a consequent need for herbicides, so the savings from using less fuel, time, and labor. may be offset by the cost associated with the increased use of herbicides (Basch et al., 2009). Farmers were more inclined to use conservation tillage if they have concerns about soil health and believe adoption will improve the soil health of their farm (Wang et al., 2019).

MATERIALS AND METHODS

THEORETICAL FRAMEWORK

Utility maximization is the theory that underpins this research. Thus, when a farmer decides whether to adopt a certain technology or innovation, he considers not just how to maximize profit from the invention, but also how to achieve the highest level of utility which is referred to as utility maximization (McConnell et al., 2009). According to the hypothesis, a farmer would adopt no-till/reduced tillage if the expected benefit derived from adoption is greater than the expected utility derived from non-adoption. The generic utility framework is defined as follows:

$U_{ij} = V_{ij} + \varepsilon_{ij}$ (1)

Where,

U_{ij} is the i^th farmers' highest expected utility derived from choosing alternative j,

V_{ij} is the systematic utility (deterministic part) that would be maximized,

X_{ij} denotes a vector of explanatory variables affecting no-till/reduced tillage adoption, and

ε_{ij} represents the random error term

j = 1,…,j and k = 1,…..,k are the alternatives being considered

It is assumed that the farmer will select no-till/reduced tillage over other alternatives based on the highest level of utility. This implies that if adoption will enhance the level of utility, then the farmers will select that option. Therefore, the probability that alternative j will be chosen is given by

$$P_i\,(j) = \Pr\left(U_{ij} \geq U_{ik}\right)$$

$$= \Pr\left(V_{ij} + \mathcal{E}_{ij} \geq V_{ik} + \mathcal{E}_{ik}\right)$$

$$= \Pr(\mathcal{E}_{ki} - \mathcal{E}_{ij} \leq V_{ij} - V_{ik}) \quad (2)$$

for all j, k ϵ P_i, where P_i is the choice set for participants i[P_i = {j, k} = {Adopt, Don ′ t Adopt}].

The net profit after adopting technology is given by,

$$\pi = \pi_i^1 - \pi_i^0 \quad (3)$$

The adoption decision is dichotomous where $Y_i = 1$ denotes the decision of farmer i to adopt conservation tillage and $Y_i = 0$ represents decision not to adopt.

U_i represents the utility for farmer i from decision Y_i.

Adoption occurs when

$$E\left(U\left(1,\pi_i^1,X_i\right)\right) > E\left(U\left(0,\pi_i^o,X_i\right)\right) \quad (4)$$

X_i is a vector of observed factors

Thus, the farmers' utility function, $U\left(1,\pi_i^1,X_i\right)$ is unknown so the deterministic part of utility function is $V(1,\pi_i^1,X_i)$. Therefore, equation 4 can be written as:

$$V\left(1,\pi_i^1,X_i\right) + \mu_1 > V(0,\pi_i^o,X_i) + \mu_0 \quad (5)$$

Where μ_1 and μ_0 are independent and normally distributed errors.

Hence, the utility maximization theory provides a basic framework for finding the factors affecting the farmers' conservation tillage adoption intensity in South Dakota.

Adoption is a decision-making process in which a unit (in this case, the farmer) develops an attitude toward employing a new approach and decides whether to accept or reject it (Roger, 2010). The adoption decision is represented by a binary choice variable (adopt or not) and the degree of adoption is assessed by the amount or share of farmland that uses the technology (Awotide et al., 2014). The adoption rate in this study is a binary choice decision and is measured with a dummy variable (1 = who has land under no-till/reduced tillage; 0 = who has no land under no-till/reduced tillage) and the intensity of adoption is the percentage of acres under no-tillage.

The study employed a Double Hurdle Model to estimate the determinants influencing the adoption decision and the intensity of adoption of no-till and reduced tillage.

DOUBLE HURDLE MODEL

The presented model is an improvement over the Tobit regression model in assessing adoption relationships by elaborating on the extent or rate of technology adoption. Because it incorporates two independent scenarios within the analytical framework, the model is appropriate (Garcia, 2013)

Akpan et al., (2012) stated that, in agricultural adoption studies, farmers experienced two obstacles in their decision-making processes. The first hurdle is the decision to adopt or not adopt technology, whereas the second hurdle is the rate of adoption. The double hurdle model can operate two models simultaneously. In estimating the model, the first hurdle using binary (probit) regression represents the adoption decision equation and is presented as

$$Y_i^{a*} = \beta X_i' + \varepsilon_i \tag{6}$$

$$\text{Where } Y_i^a = \begin{cases} 1, & if\ Y_i^a > 0 \\ 0, & Otherwise \end{cases}$$

Y_i^a is a decision made by the farmers on the adoption of conservation tillage practices (namely no-till and reduced tillage) in their farming system (farmers that adopt scored 1 and those that did not adopt scored 0). The Probit model assumes that the independent variables are randomly distributed and that there is no linear dependence among these variables.

It is hypothesized that factors determining the adoption decision could be different from those determining the intensity of adoption, measured here as the percentage of acres adopted under no-till. Understanding the factors determining the intensity of adoption helps devise programs and policies to scale up the adoption of no-till.

This study uses an interval regression model under the second hurdle to determine the extent or intensity of adopting no-till in the farming area. For the interval regression models, we used the following values to approximate the five categories: 1-20%, 21-40%, 41-60%, and 61-80% as our dependent variables.

The extent equation is stated as:

$$Y_i^{b*} = r_i\, Y_i^{a*} = \beta' X_i' + \omega_i \quad (7)$$

.

$$Y_i^b = \begin{cases} 1 & if \quad \alpha_1 < Y_i^{b*} \leq \alpha_2 \text{ and } Y_i^a = 1 \\ 2 & if \quad \alpha_2 < Y_i^{b*} \leq \alpha_3 \text{ and } Y_i^a = 1 \\ 3 & if \quad \alpha_3 < Y_i^{b*} \leq \alpha_4 \text{ and } Y_i^a = 1 \\ \vdots & \\ M & if \quad \alpha_M < Y_i^{b*} \leq \alpha_{M+1} \text{ and } Y_i^a = 1 \end{cases}$$

Where i indicates the observation, Y_i^{b*} is a latent outcome variable, Y_i^b is a partially observed categorical variable that indicates in which interval Y_i^{b*} lies, M is the number of intervals, $\alpha_1, \ldots, \alpha_{M+1}$ are the boundaries of the intervals (whereas frequently but not necessarily $\alpha_1 = -\infty$ and $\alpha_{M+1} = \infty$), Y_i^a is a binary variable that indicates whether Y_i^b is observed, Y_i^{a*} is a latent variable that indicates the "tendency" that Y_i^a is one, X_i' is the vector of explanatory variables for both equation (selection and outcome) as we have same sets of explanatory variables. r_i stands for the rate or intensity of using that technology adopted by the adopters. ε_i and ω_i are randomly distributed error terms associated with the adoption decision and rate or intensity of adoption equations respectively.

SURVEY DESCRIPTION

The data used in this study were obtained from a survey of commodity crop producers about their land management practices and attitudes in the eastern part of South

Dakota. The resurvey was conducted from January to March 2021. The survey was taken from the same producers who participated in the survey in 2018. For the survey, 3000 farmers were selected to participate using stratified random sampling. First, participants were contacted by letter where they were asked to respond to an online questionnaire and detailed information about the survey was mentioned. Later, those who didn't respond in the first round were contacted by mail, and questionnaires and return envelopes were attached. After a 2-week interval, the questionnaire was mailed again to get the maximum response rate. In the 2018 survey, among 3,000 participants, 708 farmers were active respondents resulting in a 30% response rate. For the 2021 resurvey, of the 687 producers we attempted to resurvey. Out of 708 respondents, 94 were no longer farming or unreachable. Since we did not have unique codes provided in the response from each, we couldn't be able to resurvey all 708. Our study included 593 eligible producers, and 350 of them responded, with a response rate of 59.0%. The outcome of this research will be significant to the policymakers, stakeholders, and government to make policies and programs targeting farmers.

DATA DESCRIPTION

STUDY OF DEPENDENT VARIABLES

For the first hurdle, the dependent variable to be modeled is in binary nature: adoption of no-till is labeled as '1' and non-adoption is labeled as '0' if farmers have any area under no-till. Similarly, for the second hurdle, the dependent variable is the percent of acres under the no-till farming system. The option to choose ranges from 1 = '1-20%', 2 = '21-40%', 3 = '41-60%', 4 = '61-80%', and 5 = '81-100%'. Among the adopters, table 3 shows that 29.7%, 13.5%, 23.4%, 9.9% and 23.4% of respondents have 1-20%, 21-40%, 41-60%, 61-80%, and 81-100% of land under no-tillage respectively Similarly, adoption of reduced tillage is labeled as '1' and non-adoption is labeled as '0' if farmers have any area under reduced tillage. In the same way, for the second hurdle model, for the second hurdle, the dependent variable is the percentage of acres under reduced tillage. The option to choose ranges from 1 = '1-20%', 2 = '1-40%', 3 = '41-60%', 4 = '61-80%', and 5 = '81=100%'.

STUDY OF INDEPENDENT VARIABLES

The independent variables described in table 1 with appropriate expectations were used to identify the factors affecting the decision to adopt and the intensity of the adoption. They included farm and farmer-specific characteristics, perceptions, and environmental attitudes. Agriculture as major, a variable is used as a sign for the farmer's technical understanding of soil erosion and conservation. Having agriculture education is thought to be linked to easier access to information about the erosion issue and better conservation practices. So, we included agriculture major as an important variable and asked them if they have agriculture as a major in their education. We expect this variable to have a positive impact on the adoption behavior of farmers. We asked whether farming is their primary occupation or not. This question elicits the farmers' dedication and time commitment, which may influence the time and money they are willing to invest in their farms. As a result, we believe that farmers who farm as their primary occupation will be more inclined to increase farm area under no-till. Further, decision years were used to address the farming experience years. So, farmers having a higher number of years farming are expected to adopt no-till. In addition to this, farmers' knowledge about the no-till technology is assessed by asking how familiar they are with it. This parameter is hypothesized to be positive in the adoption process.

We also asked farmers whether they used online tools to make farm management decisions. Because online decision tools provide guidance and advice that can help improve farm productivity, farmers who use such tools are hypothesized to be more likely to adopt no-till and increase their intensity. The result points out that 51% of the respondents use online decision support tools to get information. In addition, several papers studied that farmers having high erodible land were more inclined towards the adoption of no-till in their cropland (Prokopy et al., 2008). We included the percent of erodible land in the model to capture the interaction effects between the percent of no-till acres adoption and the erodible land. Also, we categorized it as erodible, and not erodible land based on the percentage of erodible land. The land which is 0% erodible is termed as non-erodible which was labeled '0' and the land which has a chance of 1-20%, 21-40%, 41-60%, 61-80%, and 81-100% of erodible land is termed as erodible which was labeled '1'. Similarly, among adopters, 63.7% and 36.4% reported that they have erodible and not erodible land respectively. This suggested that many of the no-till adopters operate in highly erodible land.

Wang et al. (2019) findings suggest that the farmers' perception of the importance of soil health and the economic benefits of soil health practices brings positive attitudes toward the adoption of conservation practices. Therefore, farmers' concerns about soil health were also included as an explanatory variable. We included this variable from the 2018 survey data. When farmers treat soil health seriously in making farm management decisions, we expect them to be more likely to adopt no-till and increase their area under no-till. Therefore, we asked respondents to rate the importance of soil health on their soil conservation practice adoption decisions from 1 = ‘Not Important’ to 5 = ‘Very Important’. Respondents were also asked about their perceptions to state how bailing stover or straws harm soil development. The options for the farmers to choose range from 1=Strongly to 4= strongly agree. Farmers who believe removing crop residues harms soil development are hypothesized to be more likely to use no-till and expand the area under it.

Profits are what drive farmers to adopt new technologies. So, farmers were also asked how they rate profitability after the adoption of no-till and option were ranged from 1 = ‘Reduced by >10%’, 2 = ‘Reduced by 5-10%’, 3 = ‘Very little change (within 5%)’, 4 = ‘Increased by 5-10%’, and 5 = ‘Increased by >10%’. Similarly, the yields obtained after adopting no-tillage may have a significant role in determining risk and return, as well as the farmer's desire to use no-tillage (Ribera et al., 2004). Therefore, we included the yield variable in the analysis. We take 5 different values, with 1 = ‘Reduced by less than 10%’, 2 = ‘Reduced by 5%–10%’, 3 = ‘Very little change’ 4 = ‘Increased by 5%–10%’, and 5 = ‘Increased by more than 10%’. Further, we combined the first three categories as 1 = 'No improvement', and the last two categories were combined into 2 = 'Improvement'. To capture the importance of rainfall in the adoption of no-till farmers were asked to state their concern about too much rainfall from 1= not at all to 4 = a lot. We expect that the farmers who are concerned about too much rainfall are more likely or less likely to adopt no-till and increase the percentage of no-till acres. Literature has revealed that no-tillage performs well on well-drained soil rather than poorly drained soil (DeFelice et al. 2006). To study this variable, we used soil draining capacity as an important factor in our analysis. Respondents were asked what percent of their land has slow draining soil and options were ranging from 1 = ‘0%’, 2 = ‘1-20%’, 3 = ‘21-40%’ , 4 = ‘41-60%’, 5 = ‘61-80%’ , and 6 = ‘81-100%’ .

For the detailed study of the tillage system and the farms, we categorized farms into small farms of less than 100 acres, medium farms, and large farms of more than 2000 acres.

VARIABLE STATISTICS

Table 2 shows the summary statistics of the variables used in the model. In our study area, on average 30% of farmers had agriculture as their major. Similarly, farmers had 21-30 years of farm experience, as indicated by mean value of 4.14 on decision years. Most of the respondents (76%) reported farming as the primary occupation in the study region whereas farmers were familiar with conservation tillage, as indicated by the mean value of 0.96 on level of knowledge. Of the farm characteristics, most respondents (56%) had erodible land. The distance from the farm to the field was on average 9.78 miles. Of the attitudes and perceptions, farmers were moderately concerned about the soil health as indicated by the mean value of 3.11. Farmers’ perceived profitability was increased by 5%-10% as indicated by a mean value of 3.35. Among the respondents, on average 31% perceived yield improvement. While 91% of farmers were concerned about too much rainfall and 89% indicated slow draining soil of their cropland.

COMPARISON OF MEANS BETWEEN ADOPTERS AND NON-ADOPTERS

T-tests are used in statistical analysis to identify if there are statistically significant differences between the means of the two groups. Two-tailed t-tests were used to analyze the sample mean differences between farmers who adopt no-till and those who do not. The following sample means were chosen to test the null hypothesis if there is noticeable difference between adopters and non-adopters:

$$\text{Null hypothesis } (H_O)\text{: } \tilde{x}_A = \tilde{x}_{NA} \quad (8)$$

Similarly, the alternate hypothesis depicts the significant difference between no-till adopters and non-adopters.

$$\text{Alternate Hypothesis } (H_A)\text{: } \tilde{x}_A \neq \tilde{x}_{NA} \quad (9)$$

Mathematically, the t-test is calculated by using the given formula:

$$t^* = \frac{\tilde{x}_A - \tilde{x}_{NA}}{s^2 \sqrt{\frac{1}{N_A} + \frac{1}{N_{NA}}}} \quad (10)$$

Where $\tilde{x}_A$ = sample mean of adopters and $\tilde{x}_{NA}$ = mean of non-adopters. N_A and N_{NA} are the sample size of no-till adopters and non-adopters respectively and S^2 is the sample variance.

CORRELATION MATRIX

Multicollinearity, if it exists, can lessen the accuracy of the estimated coefficient and p- values. The correlation matrix depicts the relation between independent variables. Generally, the threshold correlation value is 0.6. Table 5 shows the highest absolute correlation between rainfall and drainage which is 0.26. Since there are no highly correlated variables, we can assume that the estimations are efficient. To find potential multicollinearity effects, pairwise correlations were explored (Table 5).

RESULTS AND DISCUSSION

DESCRIPTIVE STATISTICS

ADOPTION STATUS

Figure 2 shows in the study area 57% and 43% of respondents were no-till adopters and non- adopters respectively. This adoption rate, based on our survey data, is slightly higher compared with the agriculture census data of 2017, according to which around 52.4% of the farmers had adopted no-till in their cropland. The percentage of no-till adopters and its distribution are based on the percentage of no-till acres adoption in South Dakota. Among total respondents, 43%, 17.0%, 7.8%, 13.4%, 5.7% and 13.4 of respondents have 0%, 1-20%, 21-40%, 41-60%, 61-80%, and 81-100% of land under no-tillage respectively. Among the adopters, Table 3 shows that 29.7%, 13.5%, 23.4%, 9.90% and 23.4% of respondents have 1-20%, 21-40%, 41-60%, 61-80%, and 81-100% of land under no-tillage respectively. Similarly, 61.9% and 38.1% were adopters and non-adopters of reduced tillage respectively. This adoption rate, based on our survey data, is relatively high compared with the agriculture census data of 2017, according to which around 29.4% of the farmers had adopted reduced tillage in their cropland Among the total respondents, 13.8%, 4.5%, 17.1%, 11.4%, and 15.0% of respondents have 1-20%, 21-40%, 41-60%, 61-80%, and 81-100% of land under no-tillage respectively. Among the adopters, Table 4 shows that 22.3%, 7.3%, 27.7%, 18.5%, and 24.3% of respondents have 1-20%, 21-40%,41-60%,61-80%, and 81-100% of land under no-tillage respectively

Figure 3 shows the percentage distribution of erodible land based on the adopters and non-adopters of no-till. Among adopters, 63.6% and 36.4% reported having erodible and non-erodible land respectively. Similarly, among non-adopters, 48.9% and 58.1% reported having erodible and non-erodible land respectively.

TYPES OF FARMS AND DIFFERENT TILLAGE SYSTEMS

In the study area, based on the number of farms, 15.3%, 76.6%, and 8.1% are small, medium, and large farms respectively. Similarly, based on the number of acres, small, medium, and large farms comprise 0.3%, 57.9%, and 41.7% respectively.

Farmers are adopting different types of tillage in their cropland like conventional tillage, no-tillage, and reduced tillage. Figure 4 showed that a higher percentage of cropland under reduced tillage followed by no-tillage and then conventional tillage which comprises 38.1%, 34.9%, and 27 % respectively. But, when we categorized farms, we found different trends in the adoption of different tillage systems.

For example, in the small farms, farmers were more inclined towards conventional tillage (51.9%), followed by no-till (34.9%), and then reduced tillage (13.8%). The medium farmers had a lower percentage under no-till (27.4%) while they had slight differences in the percent of acres under reduced tillage (37.6%) and conventional tillage (35.0%). But, in the large farms, we found a completely different trend than in small and medium farms. The area under no-till was greater than both reduced tillage and conventional tillage.

NO-TILLAGE SYSTEM

In the study area, there are a higher number of medium farms, i.e 75.1%, but based on the number of acres, large farms comprise a high share i.e 54.2% (figure 5). We found the same number of small and large farms but the ratio of acres of large farms to small farms under no-till is very high. Only 12.4% of total farms were larger farms that are practicing no-till farming. Having such a small number contributes to greater acres of land under no-till. Figure 6 indicates that most of the large farms are adopting no-till on below 50% of their land. These statistics showed that we have plenty of room to increase large farms towards no-till adoption.

REDUCED TILLAGE SYSTEM

Figure 7 reveals that there are a greater number of medium farms (80.9%) which comprises 57.2% of acres under reduced tillage in the study area. These numbers are greater than the medium farms under no-till. But there is a slightly low number of small and large farms practicing reduced tillage when we compare them with small and large farms under no-till adoption. Similarly, most of the large farms are adopting reduced tillage in a higher portion (41-60%) of their land compared to no-till in the study area. Overall, large farms are found adopting more than 50% of acres under reduced tillage. The interesting thing is that though most of the large farms practiced reduced tillage in a higher percentage of their land, large farms have more land under no-till than the reduced tillage.

ADOPTION STATUS OF NO-TILL AND REDUCED TILLAGE

Figure 9 indicates that 43.5% of the total respondents are practicing both no-till and reduced tillage in their cropland. In the study area, some farmers are adopting either reduced tillage or no-till only. The percentage of adopters for reduced tillage only is higher than no-till which comprises 18.3% and 13.8% respectively. Among the total respondents, 42.7% are found to be non-adopters which means they neither adopted no-till nor reduced tillage in their cropland.

TILLAGE PRACTICES AND THE CHALLENGES

Table 5 showed that there is the highest percentage of respondents who use a no-till as an alternative to the conventional tillage. Nearly 57.9% of farmers reported that they adopt no-till in some years but use conventional tillage in other years. It is found that only 13.3% are adopting continuous no-till. In the study region, mainly farmers are focused on corn and soybean production on a large scale where 3.7%, 16.1%, and 9.0% of farmers use no-till only for corn and only for soybeans, and all crops respectively. There is significantly low no-till adoption for corn as reported by several pieces of literature.

The farmers are facing challenges in the adoption of no-tillage, that’s why only 13.3% are adopting continuous no-tillage. Among many challenges (table 6), most of the farmers (31.8%) reported too much soil moisture in the field and delayed planting due to the slow soil warming in spring. Similarly, most farmers perceive the increased risk of herbicide resistance under no-till in long run as a serious issue in the adoption of no-till and many farmers are reluctant to use it (D'emden and Rick, 2006). Around 19.2% of the farmers reported the increased dependency on herbicides as a major hurdle in adoption. Several works of literature stated that the adoption of no-till may result in an increase, or the same yield as compared to the conventional tillage (Grandy et al., 2006; Lalani et al., 2017; Edralin et al., 2017). Normally, farmers want to see quick results and will adopt if they perceive profitability of certain technology but no-till has benefits when use in a long run. Therefore, in the study area, 13.4% of farmers reported low yield as the major reason behind not adopting continuous no-till in their fields.

T-TEST

Table 7 shows the comparison between adopters and non-adopters of No-till farming. Age, agri-major, education, decision years, primary occupation, knowledge, Distance, Drainage, and Rainfall were not statistically different. Statically significant differences between adopters and non-adopters were found for farm acres, erodible land, yield, and profitability.

Results indicate that the mean value (1.77 acres) of farm acres among adopters is greater than those who did not adopt (0.84 acres), suggesting that adopters have a greater number of farm acres than non-adopters. The mean value of those who reported having erodible land (0.63) for adopters reveals that 63% of adopters have erodible land, which was significantly higher than 49% for non-adopters. The mean value of the perceived cash crop yield (0.41) for adopters indicates that 41% of adopters perceived yield increase due to no-till adoption, which was significantly higher than non-adopters 18%. Similarly, the mean value for perceived profit (3.54) for adopters was higher than for non-adopters (3.06), indicating that most of the adopters perceived an increase in profit as compared to non-adopters. There was a significant difference in the mean rainfall between adopters (15.93) and non-adopters (19.51).

DOUBLE HURDLE MODEL

FACTORS AFFECTING NO-TILL ADOPTION DECISIONS AND THEIR INTENSITY

The factors affecting farmers’ no-till adoption and its intensity in South Dakota are presented in Table 9. The first hurdle relates to whether the individual adopts no-till or not, and the second refers to the intensity of adoption. Farm and farmers' characteristics were also included as explanatory variables to show the effects of these attributes on the likelihood of no-till adoption and increase its intensity. The results of the study revealed that primary occupation didn't play a significant role in the adoption decisions, but it was negatively significant with the adoption intensity. Primary occupation determines the time a farmer can spend farming, while no-till on more acres save time. So, farmers might think that he can work maximum time in the field and don't necessarily need alternatives for it. This might be the one reason that farmers with primary occupation don't like to expand area under no-till. Another possible explanation for this outcome might be that no-tillage adoption might be risky under certain circumstances when proper conditions are not met. Saak et al. (2021) mentioned that the benefits of the adoption of conservation practices take years to manifest. Therefore, farmers who are fully relied on farming as a source of their family income might feel risky and quite hesitant to expand new technology on most of their cropped land.

Consistent with the findings of Akter et al. (2021), we found size of cropped area is statistically significant at 1% and positively influenced a farmers' no-till adoption decision. Thus, the bigger the farm area the more likely to adopt no-till in their farming system. This result could be explained as those farmers who have more acres, and they adopt no-till on a certain portion of their land and by chance, if there is the failure of the practices then this wouldn't result in a big loss as a loss could be compensated from other portion of land. Also, larger farms achieve advantages from economies of scale (Holmes and Lee,2012; Prokopy et al., 2019).

The results further indicate that the erodible land enhances the farmers' no-till adoption decision as well as the adoption intensity. This means that the farmers who have highly erodible land are more likely to adopt no-till and expand the cropped area under no-till. As indicated by Blanco-canqui et al. (2009), no-till enhances the near-surface soil aggregate and soil organic carbon which provide resistance against the raindrop impacts on the soil that results in improving soil structure and reducing soil erodible land. Bultena and Hoiberg (1983) mentioned that the adoption of conservation tillage is based on the potential of the erosion of their cropland. Similarly, conservation tillage was found to be successful in highly erodible land which predominantly motivated farmers to adopt it (Reimer, Weinkauf, and Prokopy, 2012).

In addition to these farmers and farm characteristics, we found farmers' attitudes and perceptions play a significant role in both adoption and intensity of adoption processes. We found that farmers' concern about too much rainfall had negative impacts on the intensity no-till adoption in their field and is statistically significant at 5%. This shows that when farmers believe too much rainfall is not good for soil and crop development then farmers are likely to practice no-till. In no-till, a large amount of crop residues is left on the soil which automatically conserves moisture and if farmers think too much rainfall will increase the overall moisture content of soil, then farmers might not be interested in the no-till adoption.

Similarly, we also introduced the economic aspect as one of the important explanatory factors in the adoption decision. The result showed that when farmers perceive an increase in profitability after no-till adoption were more likely to increase the acres under no-till. Rouabhi et al. (2019) found that no-till reduces the cost of production and increases farm profitability. So, farmers who give importance to profitability are likely to expand farm areas under no-till. It is consistent with the findings of Mazvimavi and Twomlow (2009). According to them, profitability was found to increase with the increase in farming areas under conservation tillage. In addition to this, when farmers perceive improvement in the yield after no-till adoption then they are more likely to adopt no-till and increase its intensity. This could be explained as yield being the critical factor that limits the adoption of any conservation practices but when farmers find an increment in the yield after adoption then they want to adopt and expand their cropland under such practices. One can get benefits from yield with long-term adoption and improved soil quality under no-tillage (Zhao et al., 2017).

Further, Table 9 indicated that under weather and soil characteristics, actual rainfall plays a pivotal role in farmers' decisions. Rainfall was found to have a negative association with the no-till adoption decision. This can be inferred as the farmers of the certain area that receives more rainfall are less likely to adopt no-till on their cropland. Soil moisture is a major concern and presents a significant challenge in the decision to adopt no-till. Having slow drainage along with high rainfall such condition increases the moisture content of the soil and in addition to this, if farmers adopt no-till practices then the cropland will be unfavorable for farming due to excess moisture in the soil. Defliece et al., (2006) found that soil drainage had more effect on no-tillage than conventional tillage. NT had slightly greater corn and soybean yield on moderate to well-drained soil but lower yield than CT on poorly drained soil.

FACTORS AFFECTING REDUCED TILLAGE ADOPTION DECISION AND ITS INTENSITY

In the study area, most of the respondents were found to have reduced tillage adoption in their farming system. Therefore, to compare the adoption behavior of farmers between two tillage systems, we included the reduced tillage in our study. Table 10 shows farmers and farm characteristics like primary occupation, and farm acres significantly affect their adoption decision process only while agri-major affect their decision towards the intensity of adoption only. The number of years in decision making had an impact on both adoption and the intensity of adoption.

The results could be explained as farmers who had taken agriculture as major in college are more likely to expand their area under reduced tillage. Similarly, decision-making years had a positive impact on the adoption decision and the extent of adoption. The more years farmers have been engaging in farming, the more likely it is to adopt reduced tillage and expand cropland under it. The farmer who is farming for a very long time must be more conscious of how their soil is losing fertility and how their annual output is declining. An experienced farmer would therefore choose to implement the reduced tillage technology since he is more aware of the advantages of soil conservation. This outcome is consistent with findings by Laxmi and Mishra (2007), who observed that farming years had a positive relationship with the adoption in a study of factors affecting the adoption of resource conservation technology, the case of zero tillage in rice-wheat farming. Similarly, farmers who consider farming as a primary occupation have more probability of adopting reduced tillage whereas it doesn't have any impact on the intensity of adoption.

Further, the farm size coefficient was positive and significant at 5%, indicating that farm size plays an important role in the adoption decision process. This implies that farmers who operate on large farms are more likely to adopt reduced tillage. Similar findings were observed by Wang et al, (2010) in the study of determinants of conservation tillage. To lower average production costs and increase profit per acre of land, larger farms could spread the initial investment in equipment over more acres (Prokppy et al. (2019). Also, the reason behind this could be that having a greater number of acres means high-risk takers. Because adoption can be done only on certain portions of land and if found profitable can expand to a large portion of cropland if not, they can discard those practices, where the loss incurred, will be compensated by other means. Lee and Stewart (1983) observed that fewer cropping acres reduce the adoption rate, in the study of landownership and the minimum tillage. Distance was significant at 1%. This can be inferred as the greater the distance between home to field the farmers were more likely to adopt reduced tillage in their cropland.

Table 10 further shows that farmers' attitudes and perceptions also play an important role in the adoption process. The farmers' concern about too much rainfall had a positive impact on the extent of no-till adoption. This result could be explained as there might be chances of erosion due to heavy rainfall and in such cases, if the farmers increased the area under reduced tillage, the residues on the land act as barriers to soil erosion. Knowler and Bradshaw (2007) observed that farmers' awareness of and concern for soil erosion had a positive effect on farmers’ adoption of conservation agriculture practices such as conservation tillage.

COMPARISON BETWEEN FACTORS AFFECTING NO-TILL AND FACTORS AFFECTING REDUCED TILLAGE

Table 9 and Table 10 showed that most of the factors affecting adoption behavior were different between no-tillage and reduced tillage. The only common factor affecting the probability of adoption of no-till and reduced tillage was farm size and primary occupation but primary occupation had negative influence on the no-till adoption and its intensity of adoption while it had positive effect on the probability of reduced tillage adoption. The findings indicated that farmers having erodible land were likely to adopt no-till and increase its intensity, but we didn't find any impact on the reduced tillage adoption but had negative and significant impact on extent of reduced tillage adoption. This can be explained as that reduced tillage involves full-width tillage which causes disturbances to the soil and in such case, farmers who believe disturbances causes cause erosion then farmers wouldn't adopt such practice in the higher percentage of their land We found that distance had a negative and significant impact on no-till adoption intensity while it had positive impact on the extent of reduced tillage adoption. A possible reason behind this result could be that under no-till practices there is a higher chances of weed infestation and must do frequent visits and give attention as compared to reduced tillage. Therefore, people who have farms far from home might hesitate to adopt this practice.

Our result indicated that the increase in farmers perceive profitability change after no-till adoption had positive impact on the no-till adoption but no effect on the reduced tillage adoption. Because farmers are mostly driven to adopt any new technology when it is more profitable than existing technology. Likewise, farmers who had concern about soil health were less likely to increase cropland under reduced tillage. Similarly, farmers who were concerned about rainfall were less likely to increase the area under no-till whereas more likely to increase the area under reduced tillage. The soil without any tillage already conserves enough moisture and if there is too much rainfall then there, we be excess moisture which is not good for the crops as it might cause root diseases. But, under reduced tillage, there is full-width tillage that helps to dry soil comparatively and the residues present on the soil also act as barriers for the soil erosion resulting from excess rainfall.

Our findings also indicated that yield and actual rainfall were two other factors that had an effect on the no-till adoption but did not have any effect on reduced tillage adoption.

CONCLUSIONS

CONCLUSIONS AND IMPLICATIONS

This thesis aims to identify factors influencing no-till adoption decisions and the intensity of adoption among farmers in South Dakota. The study observed that adopters (57%) of no-till are more than the non-adopters (43%) whereas 61.86% and 38.14% were adopters and non-adopters of reduced tillage respectively in the area. It was therefore concluded that many of the farmers had adopted reduced tillage in the field. T-tests were conducted to determine whether the means of adopters and non-adopters were statistically equal for all determinants potentially influencing the adoption of no-till. We employed a double hurdle model to test our hypothesis. From the model, we concluded that adoption and intensity of adoption are two different decision processes in which most of the factors affecting adoption are not affecting the intensity. It was concluded from the results of the double hurdle model that farm size, erodible land, yield, and actual rainfall were the major factors affecting the farmer's no-till adoption decision, whereas primary occupation, erodible land, distance, profitability, yield, rainfall concern, and actual rainfall were the factors affecting the intensity of adoption. Based on the findings, farmers who found an increase in profitability after no-till adoption would utilize no-till on more of their acres. Erodibility was noticed to be positive in the adoption decision. So, outreach efforts to promote no-till aimed towards the farmers, who have operated in highly erodible land, may be more successful in increasing the intensity of no-till adoption.

Further, a comparison between determinants of no-till and reduced tillage intensity shows that most of the significant factors affecting the adoption behavior and its intensity are different in the two systems. For example, erodible land, soil development, yield, and drainage had a significant impact on no-till adoption while decision years and primary occupation were only significant on the reduced tillage adoption. The common factors affecting the farmers' adoption decision were primary occupation and farm size. Similarly, primary occupation, erodible land, profitability, yield, and actual rainfall were significantly affecting the extent of no-till adoption while agri-major, decision years, and were significant for the extent of reduced tillage adoption. Erodible land, distance, rainfall concern were common factors affecting the extent of adoption of both tillage systems.

The findings of this study provide guidance for future extensions and research in this area. For example, the study shows that an increase in perceived profitability change enhances the likelihood of adoption. So, this helps policymakers in the formulation of policy to support farmers in the beginning years which will help to increase the adoption rate. Our results suggest that farmers who have high erodible land are more likely to expand no-till acres. As a result, outreach efforts aimed towards these populations may be more successful in increasing the percentage of no-till acres adoption. Similarly, Soil characteristics may affect which types of tillage should be practiced. For example, farmers' having slow-draining soil were less likely to adopt no-till. So, these things would be helpful for policymakers in implementing suitable conservation practices in the respective areas.

LIMITATIONS OF THE STUDY

This study has several limitations. This is a survey-based data collection in which some of the respondents left the questions unanswered as they might be inappropriate to their situations. We could not include all the surveyed respondents in the analysis due to the missing values. Similarly, the choice of variables is a challenging task as well. The decision to adopt no-till and expand cropped land under this practice by farmers may be influenced by a variety of factors, however, the survey instrument only included a small number of alternatives, which may have left out some important factors.

FUTURE RESEARCH

Future work could be done to compare and analyze the behavior of the respondents of other parts of the state where maximum numbers of no-till adopters are present. Based on the methodologies of this thesis, the research could be expanded on other states which might shed additional light on the determinants of no-till adopters at the inter-state level and help to identify the no-till adoption trend.

Similarly, most of the no-till adopters and non-adopters perceive there is a severe weed problem and a higher risk of herbicide resistance under the long use of no-till in the field. Even with the low input cost in the conservation tillage adoption, the cost associated with the increased use of herbicides offset the saving that is obtained from the adoption of CST. Therefore, there is an opportunity for future research to consider sustainable weed management in the no-tillage expansion decisions.

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Table 1: Description of explanatory variables employed for the model

Category	variable	Description
Farmer Characteristics	Agriculture as major	Completed agriculture major in college (yes=1, No=0)
	Decision-making years	Number of years as primary decision taker (Less than 5 years =1, 5 – 10 years =2, 11 – 20 years 4, 21 – 30 years= 5, More than 30 years =6)
	Primary occupation	Farming as the primary source of income (1 = yes, and 0= No)
	Level of Knowledge	Famer who knows about no-till 0= unfamiliar, and 1 = Familiar
Farm characteristics	Farm size	Land size of arable land (acres)
	Erodible land	Erodible land=1 Non-erodible land=0
	Distance	Distance from home to field
Attitudes and Perceptions	Soil health	The farmer who has concerns about soil health Not at all=1, Slightly=2, Moderately=3, A lot =4)
	Soil development	Farmers who think bailing stover or straws harms soil development Strongly disagree=1, Disagree=2, Agree=3, strongly agree =4)
	Profitability	Farmers rate profit after adopting no-tillage (Reduced by >10% =1, Reduced by 5%-10% =2, Very little change (within 5%) = 3, Increased by 5%-10% = 4, Increased by >10% = 5
	Yield	Farmer’s perceived yield rate (Reduced by >10% =1, Reduced by 5%-10% =2, Very little change (within 5%) = 3, Increased by 5%-10%=4, and increased by >10% = 5

Table 1 (continued)

Weather and Soil Characteristics	Rainfall concern	Farmers' concern about too much rainfall Not at all =1, Slightly=2, Moderately=3, A lot=4)
	Actual rainfall	Amount of rainfall
	Drainage	Farmers' having slow draining soil issues in their cropped land Yes = 1 No = 0

Table 2: Distribution of Farmers according to their Socioeconomic Characteristics

Category	Variable	N	Mean	Std. Dev.	Min	Max
Farmer Characteristics	Agri major	236	0.305	0.461	0	1
	Decision years	291	4.137	1.169	1	5
	Primary occupation	290	0.762	0.426	0	1
	Level of Knowledge	332	0.964	0.187	0	
Farm characteristics	Farm size	349	1388.809	2642.619	0	34942
	Erodible land	327	0.569	0.496	0	1
	Distance	331	9.784	44.144	0	600
Attitudes and Perceptions	Soil health	346	3.116	0.808	1	4
	Soil development	632	2.647	0.786	1	4
	Profitability	317	3.347	0.987	1	5
	Yield	319	3.201	0.989	1	5
	Rainfall concern	347	0.919	0.273	0	1
Weather and Soil Characteristics	Actual rainfall	313	16.43	1.49	13.28	19.36
	Drainage	336	0.896	0.306	0	1

Table 3: Distribution of respondents by percent of acres on cropland under No-till

Percent of acres on cropland under No-till	Frequency	Percentage (%)
1-20%	57	29.69
21-40%	26	13.54
41-60%	45	23.44
61-80%	19	9.90
81-100%	45	23.44

Table 4: Distribution of respondents by percent of acres on cropland under Reduced tillage

Percent of acres on cropland under Reduced tillage	Frequency	Percentage (%)
1-20%	46	22.33
21-40%	15	7.28
41-60%	57	27.67
61-80%	38	18.45
81-100%	50	24.27

Table 5: Pairwise correlations among independent variables

Drainage	Actual rainfall	Rainfall concern	Yield	Profit	Soil development	Soil health	Erodible land	Farm size	Distance	Knowledge	Primary occupation	Decision years	Agri-major	Variables
-0.05	0.003	0.03	0.09	0.03	0.14	0.01	0.02	0.01	-0.03	0.05	0.01	-0.09	1	Agri-major
0.14	0.05	0.07	0.12	0.21	0.06	0.06	0.09	0.06	-0.07	0.05	0.30	1		Decision years
0.16	0.02	0.14	0.10	0.15	0.15	0.16	0.09	0.22	-0.13	0.06	1			Primary occupation
0.05	0.30	0.18	0.05	0.17	0.04	0.23	-0.01	0.06	0.02	1				Knowledge
-0.02	-0.11	0.03	-0.02	-0.005	-0.21	-0.001	-0.09	-0.02	1					Distance
0.12	-0.14	0.06	0.05	0.11	0.07	0.03	0.09	1						Farm size
0.20	-0.01	0.02	-0.05	0.03	0.03	0.07	1							Erodible land
0.09	0.01	0.23	0.08	0.11	0.05	1								Soil health
0.06	0.18	0.08	0.11	0.22	1									Soil development
0.15	-0.18	0.003	0.54	1										Profit
-0.05	-0.19	0.04	1											Yield
0.26	0.01	1												Rainfall concern
1														Drainage

Table 6: Different types of tillage practices adopted in the study area

Tillage Practices	Percentage of Usage (Average for those who use practice)
Continuous no-till (always use no-till) (N=47)	13.3%
Use no-till in some years, but use conventional tillage in other years (N=205)	57.9%
Use no-till for all crops (N=32)	9.0%
Use no-till only for corn (N=13)	3.7%
Use no-till only for soybeans (N=57)	16.1%

Table 7: Challenges during continuous no-till adoption

Challenges	Percentage (Average for those who faced challenge sense
Too much soil moisture (N=164)	31.8%
Delayed planting due to slow soil warming in spring (N=164)	31.8%
Reduced crop yields (N=69)	13.4%
Increased dependence on herbicide/fungicide (N=99)	19.2%
Other reasons (Please specify) (N=20)	3.9%

Table 8: Mean significant difference between adopters' vs non-adopters' of No-tillage

Variables	Adopters			Non-Adopters			t-test
	Observation	Mean	Std. Dev	Observation	Mean	Std. Dev	
Age	202	58.19	0.94	137	59.77	1.26	1.02
Agri-major	146	0.34	0.04	90	0.24	0.05	-1.59
Education	202	2.19	0.06	137	2.09	0.07	-1.06
Decision years	176	4.16	0.08	115	4.09	0.12	-0.49
Primary occupation	176	0.79	0.03	114	0.74	0.04	-0.81
Knowledge	199	0.96	0.01	133	0.96	0.02	-0.11
Farm acres($x10^{-3}$)	207	1.77	0.23	142	0.84	0.09	-3.26***
Erodible land	191	0.63	0.04	136	0.49	0.04	-2.59**
Distance	193	9.81	2.62	138	9.75	4.52	-0.01
Drainage	199	0.90	0.02	137	0.88	0.03	-0.63
Soil health	206	3.14	0.06	140	3.07	0.06	-0.70
Soil development	199	2.60	0.06	133	2.45	0.85	-1.37
Yield	207	0.41	0.03	142	0.18	0.03	-4.67***
Profitability	190	3.54	0.07	127	3.06	0.08	-4.43***
Rainfall concern	206	0.91	0.02	141	0.92	0.22	0.15
Actual rainfall	207	15.94	0.71	142	19.51	0.92	3.11***

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 9: Double Hurdle Model on factors influencing no-till adoption and its intensity

Category	Variables	1st Hurdle (Adoption Decision) (Probability of adopting NT)		2nd Hurdle (Adoption intensity)	
		Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
Farmer Characteristics	Agri-major	0.10	0.23	3.36	5.13
	Decision-making years	0.12	0.09	1.30	2.23
	Primary occupation	-0.49*	0.28	-16.46**	6.56
	Knowledge	0.64	0.31	1.47	8.03
Farm characteristics	Farm size($x10^{-3}$)	0.56***	0.15	-0.03	0.67
	Erodible land	0.54**	0.22	11.51**	5.19
	Distance	-0.004	0.009	-0.96***	0.35
Attitudes and Perceptions	Soil health	-0.007	0.13	1.94	3.02
	Soil development	0.13	0.13	-0.21	3.09
	Profitability	0.009	0.13	9.48***	3.44
	Yield	0.69**	0.28	13.69**	6.25
	Rainfall concern	-0.19	0.40	-16.92**	8.37
Weather and Soil Characteristics	Actual rainfall	-0.02**	0.01	-0.73***	0.26
	Drainage	-0.46	0.38	5.59	8.76
		Number of obs = 193		Number of obs = 116	
		LR chi2(14) = 61.83		LR chi2(14) = 53.17	
		Prob > chi2 = 0.0000		Prob > chi2 = 0.0000	
		Pseudo R2 = 0.24		Log likelihood = -197.53	
		Log-likelihood = -97.08		Sigma = 3.20***	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Double Hurdle Model on factors influencing reduced tillage adoption and its intensity

Category	Variables	1st Hurdle (Adoption Decision) (Probability of adopting RT)		2nd Hurdle (Adoption intensity)	
		Coef.	**Std. Err.**	**Coef.**	**Std. Err.**
Farmer Characteristics	Agri-major	0.08	0.21	11.36**	5.74
	Decision-making years	0.24***	0.09	6.39***	2.37
	Primary occupation	0.73***	0.28	0.99	9.15
	Knowledge	0.17	0.32	2.76	9.50
Farm characteristics	Farm size($x10^{-3}$)	0.20**	0.08	-0.71	0.71
	Erodible land	0.16	0.21	-9.50*	5.32
	Distance	0.01	0.01	0.08*	0.05
Attitudes and Perceptions	Soil health	0.01	0.13	-4.36	3.29
	Soil development	-0.01	0.12	3.18	3.17
	Profitability	-0.03	0.13	2.62	3.45
	Yield	-0.23	0.26	-2.55	6.84
	Rainfall concern	-0.15	0.36	23.48**	9.62
Weather and Soil Characteristics	Actual rainfall	0.005	0.01	-0.14	0.28
	Drainage	0.09	0.35	0.20	10.26
		Number of obs = 188 LR chi2(14) = 45.05 Prob > chi2 = 0.0000 Pseudo R2 = 0.18 Log-likelihood = -105.05		Number of obs = 110 LR chi2(14) = 26.82 Prob > chi2 = 0.02 Log-likelihood = -191.91 Sigma = 3.24***	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Graphical representation

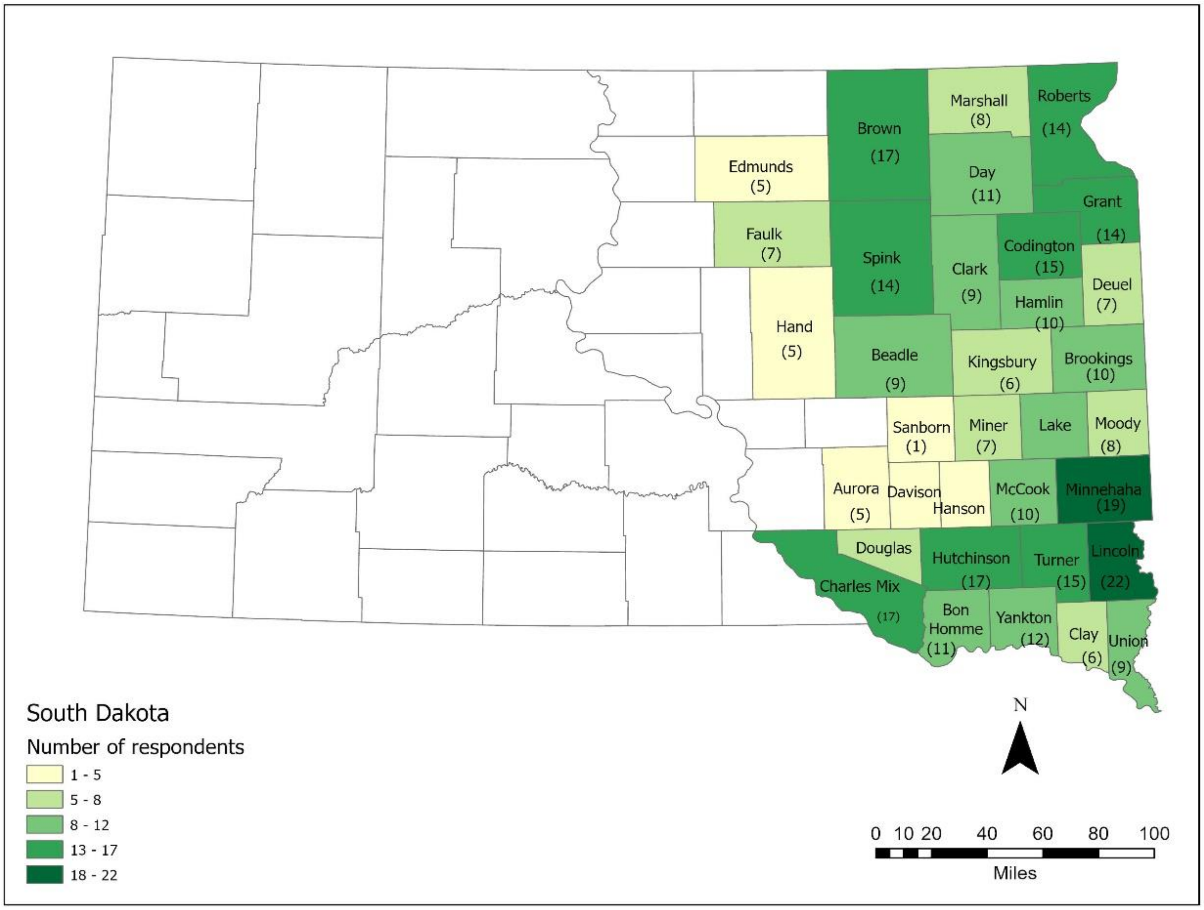

Figure 1: The map of study counties of South Dakota

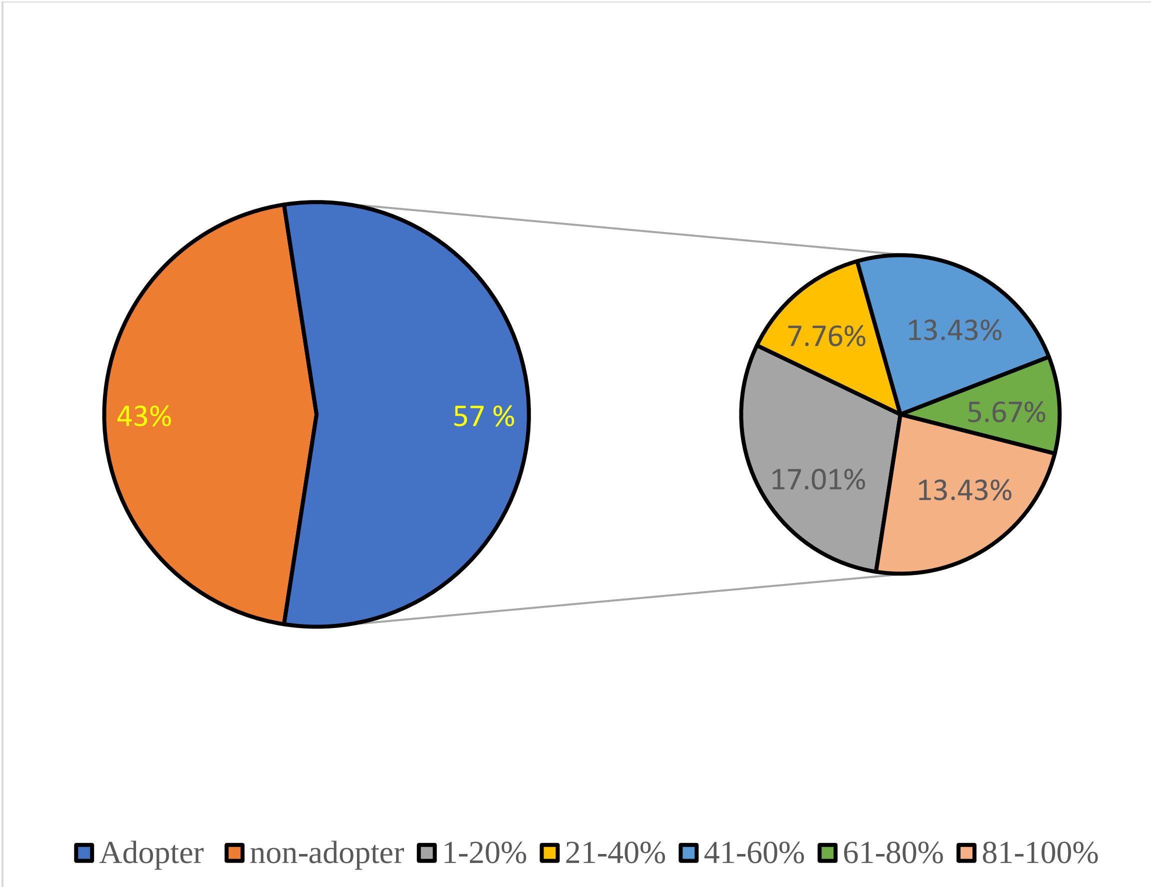

Figure 2: Percentage of no-till adopters and its distribution based on the percent of no-till acres adoption in South Dakota

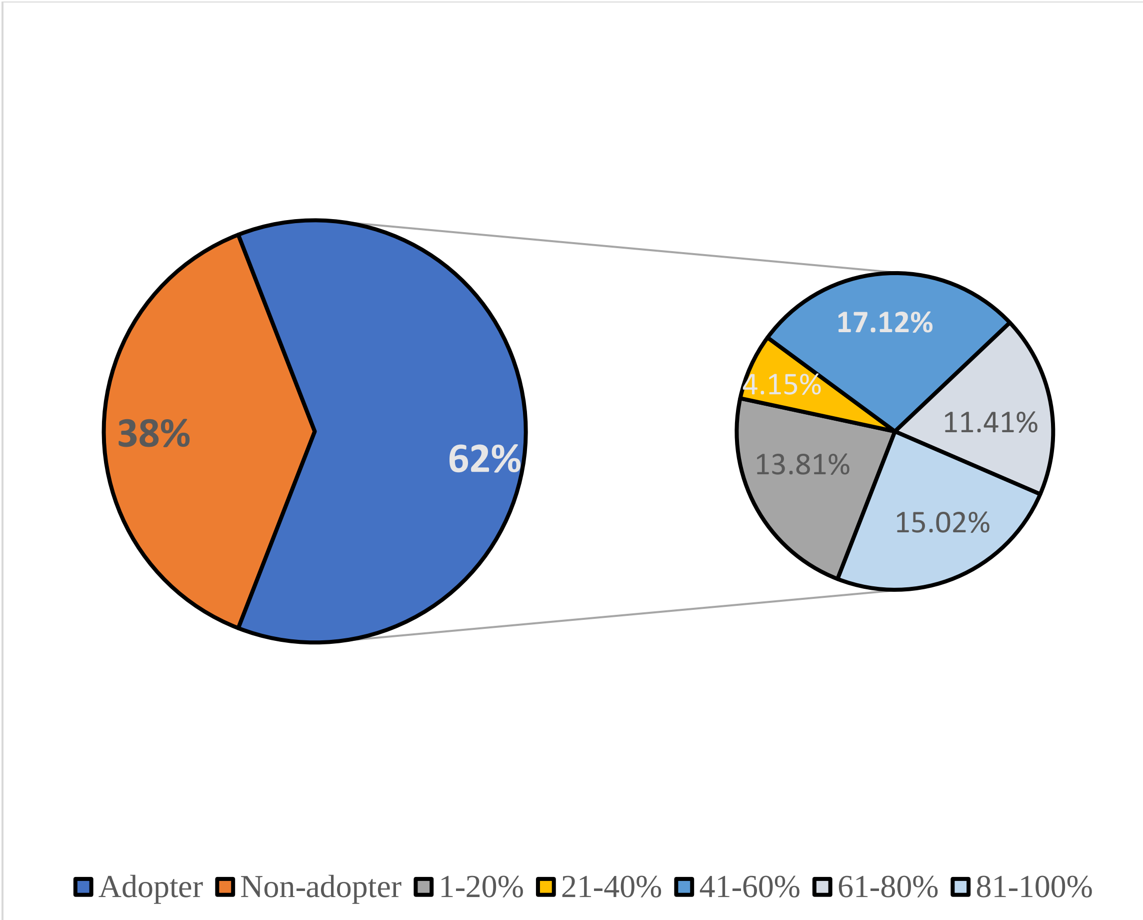

Figure 3: Percentage of reduced tillage adopters and its distribution based on the percent of reduced tillage acres adoption in South Dakota

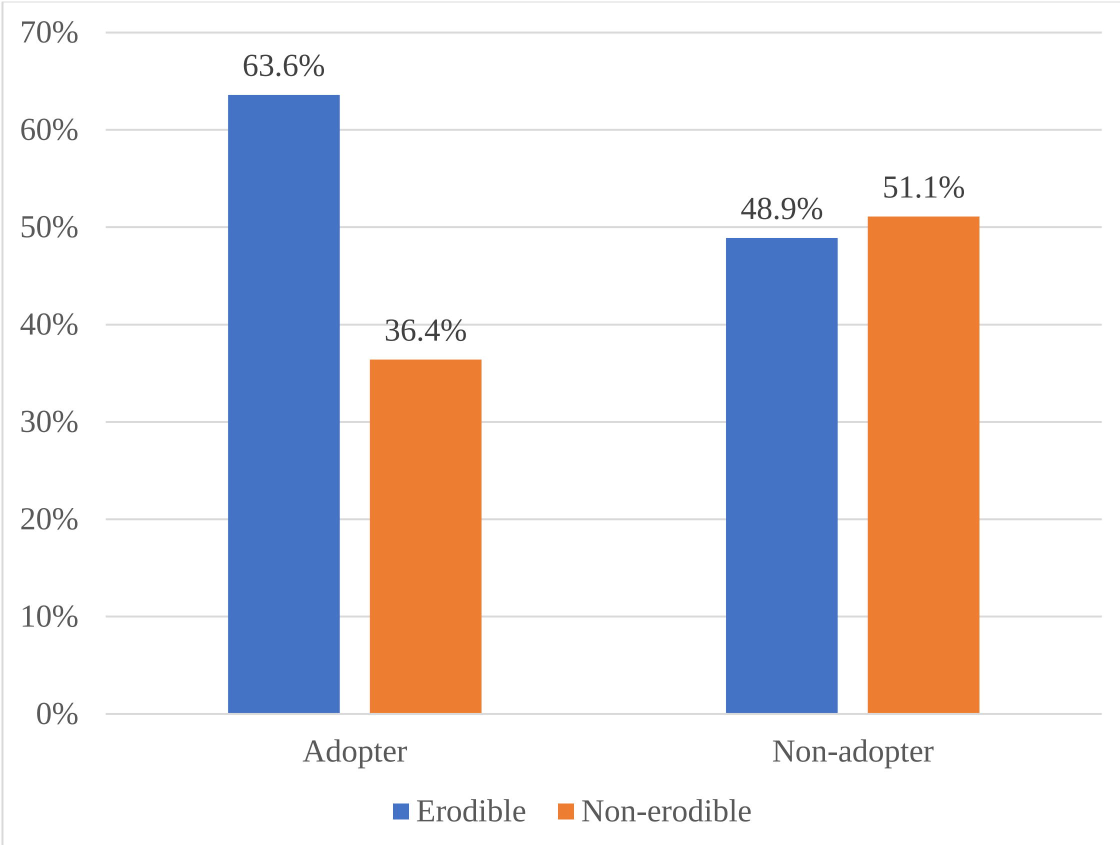

Figure 4: Percentage distribution of erodible land by adopters and non-adopters of no-till

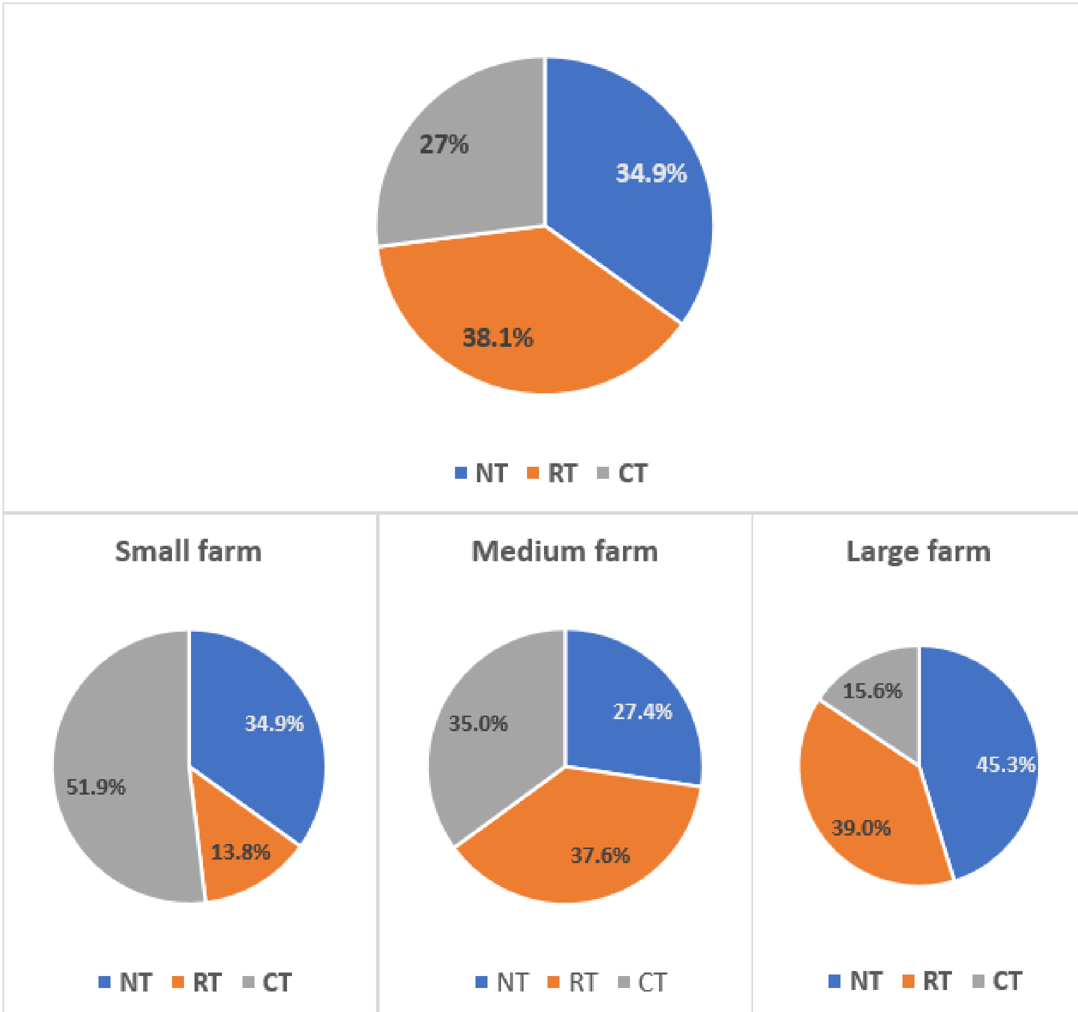

Figure 5: Different types of farm and tillage systems

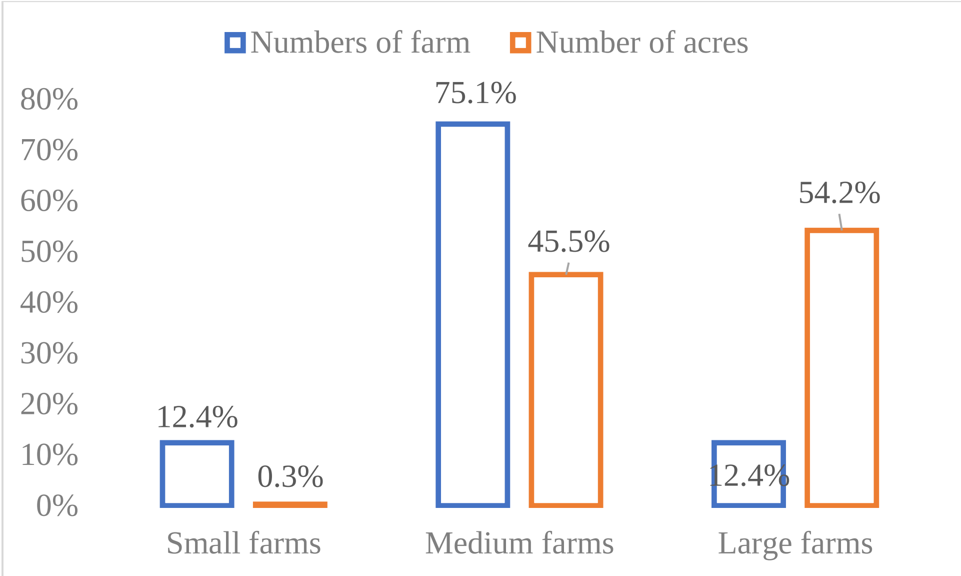

Figure 6: Different types of farms based on the number of farms and number of acres under No-till

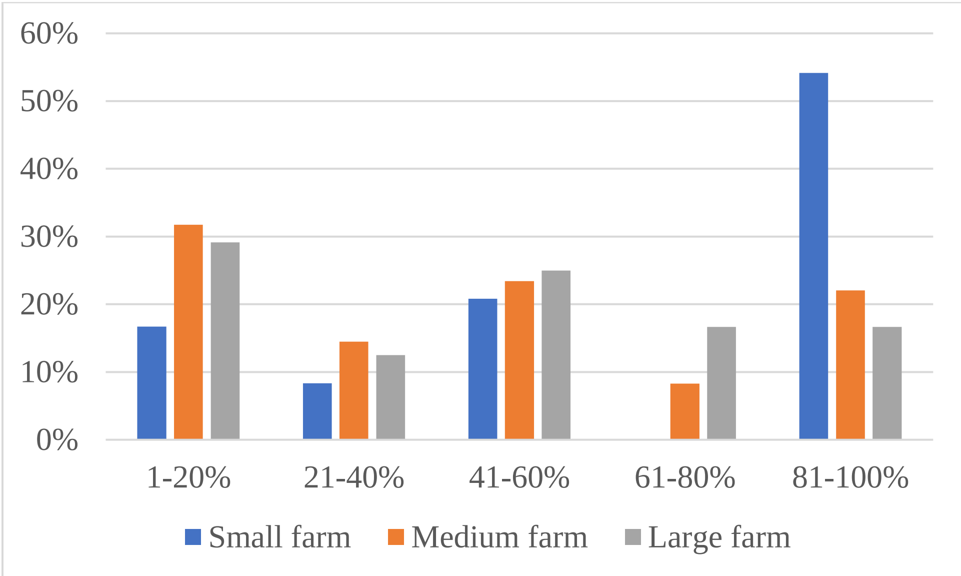

Figure 7: Different farms with percent of acres under no-till

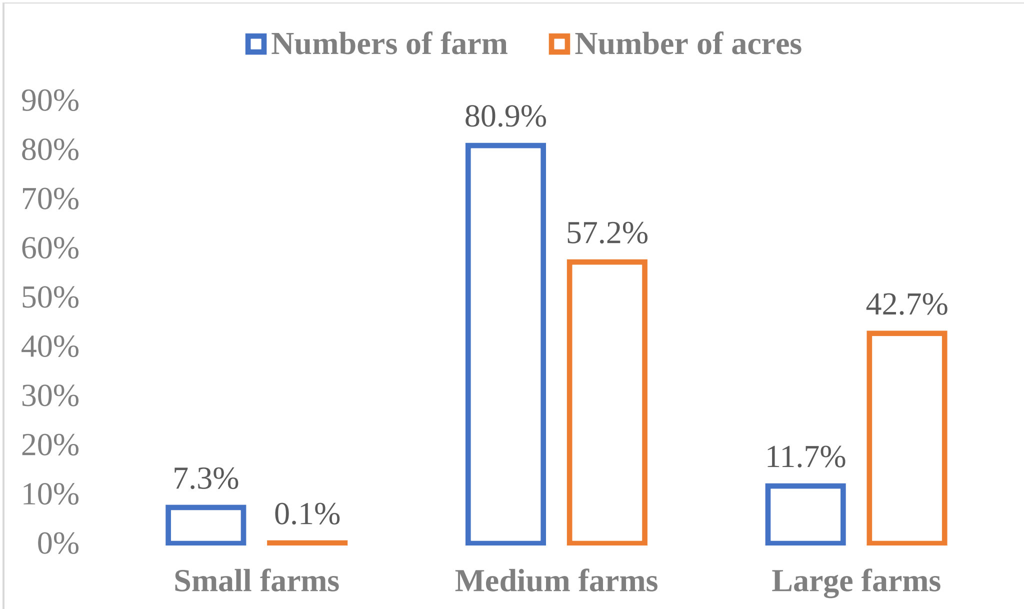

Figure 8: Different types of farms based on the number of farms and number of acres under reduced tillage

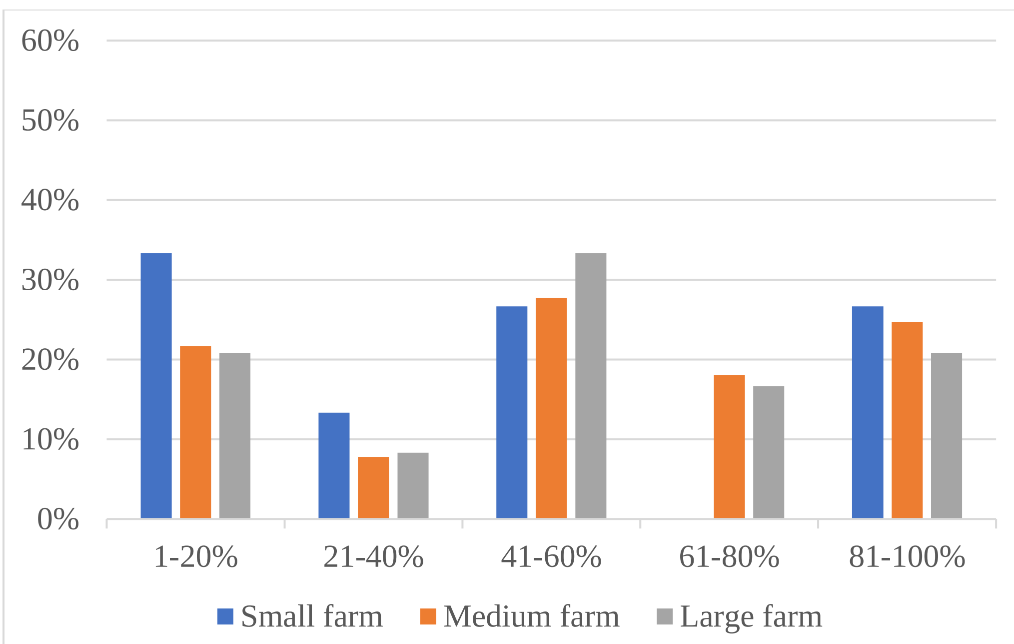

Figure 9: Different farms with percent of acres under reduced tillage

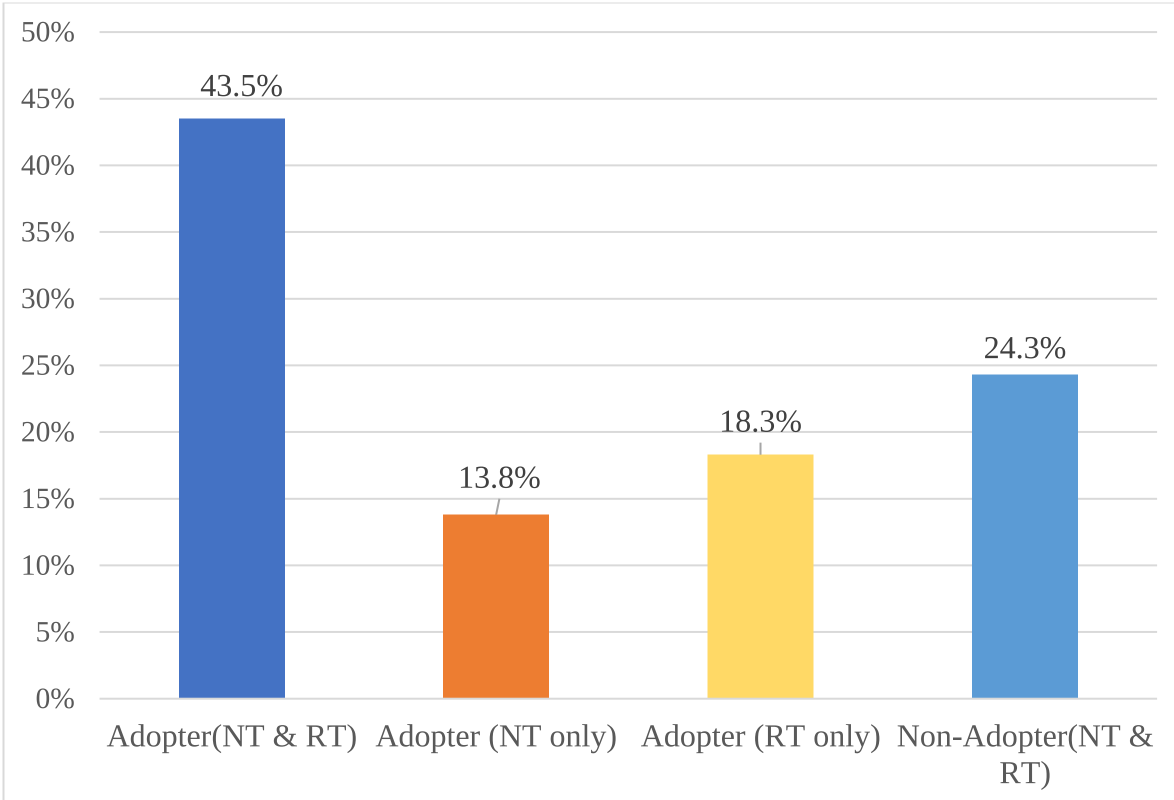

Figure 10: The adoption status of no-till (NT) and reduced tillage (RT)