

**Producer Perceptions and the Use of Conservation Practices in Middle
and West Tennessee**

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Master of Science

Degree

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ABSTRACT

To better understand the use of no-till and cover crops, this thesis utilizes a 2017 survey of row crop producers in Middle and West Tennessee to analyze producer perceptions and awareness of the likelihood of possible outcomes occurring from using no-till and cover crops. Respondents believed the most likely outcomes of using no-till and cover crops to occur were reducing soil erosion, followed by improving soil quality/health and water quality. However, they believed reducing yield variability, controlling weeds, and increasing yield were less likely to be a result of using no-till. They also believed that increasing profit, increasing yield, and reducing yield variability were unlikely to occur from using cover crops. On average, no-till users and cover crop users were more confident of the effects of using the practices than non-users. Cover crop users were more likely to believe the effects of using cover crops than abandoners. In addition, this study also uses the data to analyze whether and how producer demographics, experience in farming, and farm characteristics are correlated with their opinions of the possible outcomes of the practices. Education and both knowing about and having received a cost-share payment for cover crops were the factors that commonly influenced farmer perceptions of the effects of using no-till and cover crops, respectively.

On the other hand, since the adoption rate of cover crops was relatively low in Middle and West Tennessee, the same survey data are used to analyze the correlation between the use of cover crops and producer demographics, experience in farming, and farm characteristics. The result shows that having crop insurance and planting cotton were significantly and positively correlated with the use of cover crops in 2016.

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CHAPTER I

Introduction

The problems that humanity are now facing include not only global warming but also the degradation of soils (FOA 2015). As the population increases, more and more topsoil is lost or destroyed. The Food and Agriculture Organization of the United Nations (FAO) estimates that 24 billion tons of fertile soil or 12 million hectares of topsoil are lost each year. Approximately 25% of the earth's surface, or enough land area to feed 1.5 billion people has been degraded, and at current rates of loss, there are about 60 years of harvests left (FOA 2015). Soil erosion is a form of soil degradation that decreases the fertility of the soil and contributes to water quality degradation through sedimentation. Herbicides and pesticides can attach to soil particles. So, when soil erosion occurs, some of those contaminants are transported with soil particles and sediments, adversely impacting water quality (Al-Kaisi 2001).

Conservation practices, such as no-till and cover crops, play an important role in erosion control (Davis 1994). However, farmer adoption of conservation practices has both costs and benefits (Snapp et al. 2005; Creech 2017; Clark 2008; Triplett and Dick 2008). The public benefits of adopting no-till or cover crops include reducing soil erosion, improving soil health, and increasing soil water-holding capacity. The private benefits of adopting no-till include saving producer's time, fuel and the need for labor, while the private benefits of adopting cover crops include promoting yield stability, increasing yields, controlling weeds, helping safeguard personal health, and decreasing the need for pesticides. On the other hand, adopting no-till involves the costs of new

equipment and herbicide, as well as increasing the management burden for producers. Planting cover crops also increases producer costs and the use of chemical herbicides and pesticides.

Surveys of United States (U.S.) crop producers show that the use of no-till and cover crops is relatively limited but increasing. According to the U.S. Department of Agriculture (USDA) Census of Agriculture, 10.3 million acres of cover crops were planted in the U.S. in 2012, while 96.5 million acres of cropland were managed with no-till. The corresponding adoption rates (acres of the practices divided by acres of harvested cropland) were 3.3% for cover crops and 30.6% for no-till. In 2017, the Census of Agriculture revealed that the number of acres planted with cover crops had increased to 15.4 million acres, while acres planted with no-till rose to 104.5 million and the adoption rates had increased to 4.8% and 32.6%, respectively (USDA 2019). Thus, the census shows an approximately 50% increase in acres of cover crops and an 8% increase in acres in no-till in five years. A different USDA study indicates that in 2010-2012, about 4% of farmers used cover crops on a portion of their fields, while only 0.14% of farmers used this practice throughout their farms (Wade, Claassen and Wallander 2015). The result of a national cover crop survey conducted by the Sustainable Agriculture Research and Education (SARE), Conservation Technology Information Center (CTIC) and the American Seed Trade Association (ASTA) also suggests a steady increase in the acres of cropland planted in cover crops in the U.S. from 2012 to 2016 (SARE and CTIC 2017). The survey reported that the average number of acres planted in cover crops per

respondent was 217 in 2012, 245 in 2013, 334 in 2015, and 400 in 2016 (SARE and CTIC 2017).

However, county-level data from the 2017 Census of Agriculture reveals that the adoption rates for no-till and cover crops were much higher, at 65.5% and 7.5%, respectively, in Middle and West Tennessee¹ than in the rest of the U.S. The higher rates of adoption in Middle and West Tennessee are likely due to the highly-erodible nature of much of the soil in these regions. The 1985 Farm Bill provided that farmers who produced agricultural commodities on highly erodible land would need a conservation system to be eligible for programs administered by USDA. This policy accelerated the use of no-till in Middle and West Tennessee since most cropland in this region qualifies as highly erodible (Denton and Tyler 2002). Denton and Tyler (2002) indicated that because the cost of no-till is lower than other conservation methods, most Tennessee farmers chose to use no-till to comply with the provision in the Farm Bill. According to their study, the number of farmers using no-till increased rapidly in just a few years due to the strict implementation of the policy in 1991, as well as the improvement of herbicides, and farmers' increased confidence in the practice. Further, the Milan No-till Field Day, a large promotional event held at the UT AgResearch and Education Center in West Tennessee, has provided farmers with in-depth information on the use of no-till to

¹ For the purposes of this thesis, Middle and West Tennessee is deemed to be comprised of Robertson, Davidson, Williamson, Marshall, Giles, Cheatham, Maury, Montgomery, Dickson, Hickman, Lewis, Lawrence, Stewart, Houston, Humphreys, Perry, Wayne, Benton, Decatur, Hardin, Henry, Carroll, Henderson, Chester, McNairy, Weakly, Gibson, Madison, Hardeman, Crockett, Haywood, Fayette, Obion, Dyer, Lauderdale, Tipton, Shelby, and Lake Counties.

help them maximize productivity. After the first field day in 1981, acres in no-till started to increase (Rowsey 2014).

This study will utilize data from a 2017 survey of Middle and West Tennessee row crop producers to analyze (i) producers' opinions on the use of no-till and cover crops and (ii) the use of cover crops in Middle and West Tennessee. Given that 86.8% of respondents to the survey had adopted no-till on some or all of their cropland, the study does not analyze no-till use in Middle and West Tennessee. A better understanding of farmer perceptions of these practices and of the factors influencing farmers' use of them could help in the evaluation and design of policies and educational programs to promote their use. For example, we may find differences between producers' opinions on the impact of no-till and cover crops and what research on these practices suggests these impacts are. A failure to fully understand the impact of using no-till or cover crops may be a reason that producers do not adopt them as readily as might be expected. On the other hand, it may be that farmers have a clear understanding of the practices' benefits and choose not to adopt them for economic reasons.

What are no-till and cover crops?

Excessive development and utilization of soil have led to the loss of soil resources (Wu 2008). Thus, more and more people are trying to do something to mitigate these losses. Conservation practices are ways to care for the soil and play an important role in protecting the environment (Prokopy, Towery and Babin 2014). No-till and cover crops are methods used to conserve soil in the field by reducing soil erosion. However, these

practices can also improve soil quality, retain soil moisture, control weeds, and increase crop yields.

In a no-till system, the seeds are deposited directly into untilled soil where the previous crop remains have been preserved, and by avoiding soil tillage, farmers can avoid bringing weed seeds to the surface and stimulating them to sprout (Derpsch 2016). By not plowing or disking, no-till practices keep the soil structure intact, and crop residues increase the ability of the soil to absorb and infiltrate water, thereby reducing soil erosion and preventing sediment and nutrients from entering nearby water sources (Spears 2018; Duyck and Petit 2016).

In a cover crop system, a cover crop is grown during the off-season to leave enough residues on the soil surface for soil cover and to add organic matter to the soil (Balkcom et al. 2007). In winter, planting cover crops can reduce erosion on bare fields caused by rainfall; in the fall, cover crops can prevent weeds from growing, so there is less weeding to do in the spring (Barth 2015).

What are the effects of using no-till or cover crops?

Previous studies indicate that the benefits of planting no-till include reducing soil erosion, improving water quality, and decreasing labor needs (Uri 2000; Triplett and Dick 2008). In terms of cash crop yields, Triplett and Dick (2008) found that no-till was often more productive than conventional tillage in the southern and western regions of the U.S., but generated similar yields in the central region and lower yields in the northern U.S. Specifically, no-till performed better than conventional tillage in terms of increasing mean yields on loamy soils with a more humid and warmer climate, but worse on sandy

soils. Toliver et al. (2012) found that no-till yields were impacted by soil properties and climate factors. Improving soil health or increasing soil organic matter can reduce yield variability. Thus, some studies have found that yields were more stable when using no-till or cover crops (Soil Health Institute 2018).

Using no-till could help reduce labor costs, but may not reduce machinery operating costs because of the higher cost of new no-till implements (Uri 2000). On the other hand, instead of cultivation, no-till systems use herbicides for weed control and may require higher herbicide inputs in the first few years ("Weed control in no-till systems" 2013). Moreover, a herbicide program for weed control may increase the management burden associated with no-till (Triplett and Dick 2008).

In recent years, Balkcom et al. (2007) and Daryanto et al. (2018) have performed research on the effects of planting cover crops, most of which are positive. According to their studies, the benefits of planting cover crops include reducing soil erosion, improving soil quality, retaining soil moisture, controlling weeds, and increasing cash crop yields. However, Lira and Tyner (2018) found that there is no significant impact on cash crop yields after planting cover crops and, in terms of economic benefits, Zhou et al. (2017) indicated that compared with no cover crops, farmers' revenue gains from planting cotton with cover crops did not offset their cost of establishing the practices. However, Roberts et al. (2006) found that the use of conservation practices and herbicide-resistant cotton seed could reduce soil erosion, decrease the use of herbicide, and increase farm profits. A national survey found that planting cover crops helped control herbicide-resistant weeds, and there was a slight increase in yields of corn, soybean, and wheat on cropland where

cover crops were planted (SARE and CTIC 2016). According to a report published by SARE (2019), the longer producers use cover crops, the more crop yields will gradually increase. In addition to increasing yield, the use of cover crops can also reduce costs through decreased use of fertilizers and herbicides to reduce costs, so using cover crops could eventually increase profit (SARE 2019). Research indicates that cover crops and no-till have clear public and private benefits but that private economic return to farmers (at least of cover crops) is less clear.

Literature Review

Farmer perceptions of the effects of using no-till and cover crops

Al-Kaisi, Hanna, and Tidman (2000) conducted a survey of producers' tillage practices in Iowa. The study indicated that producers working on rugged terrain were aware that no-till can maintain yields, reduce soil erosion, reduce costs, and thus, improve soil quality and soil productivity. In addition, more than half of the respondents reported that lower yields and higher machinery conversion costs are the main factors preventing them from using no-till (Al-Kaisi, Hanna and Tidman 2000). To analyze organic farmers' attitudes towards reduced tillage, Lowry and Brainard (2017) surveyed farmers in Michigan. Their findings indicated that farmers believed the most likely benefits of reduced tillage were saving fuel, followed by improving soil quality, decreasing soil erosion and increasing water holding capacity. They found that farmers were less likely to believe that no-till would increase yields or reduce pest and weed pressure.

In a 2015-2016 cover crop survey of farmers conducted by the SARE and CTIC (2016), most respondents, including cover crop adopters and non-adopters, indicated that the most likely benefits to their farm of adopting cover crops were improving soil health (86%), reducing soil erosion (83%), and increasing soil organic matter (82%). These three benefits were also the key motivations for respondents to adopt cover crops. In addition, 45% of respondents indicated that increasing crop yields were a minor benefit, 38% believed that using cover crops was unlikely to reduce costs and, and 44% believed they were less likely to get higher economic returns from the use of cover crops.

In a 2016-2017 cover crop survey of farmers (SARE and CTIC 2017), 86% of farmers agreed or strongly agreed that planting cover crops can improve soil health. While 51% agreed or strongly agreed that cover crops help increase yield, 41% were neutral. While 49% agreed or strongly agreed that the use of cover crops can help reduce yield variability, 42% were neutral on this benefit. Approximately, 47% of the respondents agreed or strongly agreed that adopting cover crops can help reduce their inputs, such as herbicides, fertilizers, and insecticides, while 37% were neutral. In terms of economics, 45% agreed or strongly agreed that using cover crops can confer economic advantages on users over those who do not use them, while 44% were neutral. Therefore, the 2015-2016 and 2016-2017 CTIC survey reveals suggest that farmers may generally believe that using cover crops benefits soil resources by improving soil health, reducing soil erosion, and increasing soil organic matter. On the other hand, farmers may be more uncertain of the yield or economic benefits of the use of cover crops. Based on this result, farmers seem to have a good understanding of the effects of using cover crops in general

since previous research on the effects of the use of cover crops were positive in terms of improving soil resources but more uncertain in terms of economic return.

O'Connell et al. (2015) surveyed farmers, with the majority of them in North Carolina and a small number in other to understand farmer perceived benefits and challenges related to cover crops. A majority of their respondents were from North Carolina and a small number of respondents came from a variety of other areas². Their results showed that more than 50% of the 209 surveyed farmers strongly agreed that cover crops could increase soil organic matter, reduce soil erosion, improve soil moisture, and control weeds. Almost half of the respondents agreed that the practice could increase cash crop yields, while 46% of the respondents believed that incorporating residues was a challenge when using cover crops.

Factors that affect farmers' adoption of cover crops

Despite the general recognition that cover crops can have environmental benefits and are an effective means of increasing soil health and reducing nutrient and soil loss, relatively few farmers in the U.S. have adopted this practice (Arbuckle and Roesch-McNally 2015). In order to find ways to improve educational programs and increase the adoption of cover crops, researchers have increasingly focused on the factors affecting farmers' adoption. Probit and logistic regression have often been used to assess the factors that influence farmers' willingness to adopt cover crops or other agricultural best management practices (Prokopy et al. 2008).

² Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Oklahoma, South Carolina, Tennessee, Texas, Virginia, Puerto Rico, and the US Virgin Islands

Previous studies concluded that younger farmers with more education were more likely to adopt cover crops or other conservation practices (Burnett et al. 2018; Carlisle 2016; Mishra et al. 2018). Compared to farmers who did not use cover crops, farmers planting cover crops had lower farm incomes (Burnett et al. 2018) and were more likely to use irrigation systems (Bergtold et al., 2012; Snapp et al. 2005). Also, farmers with larger farms and who planted row crops such as soybeans were more likely to use cover crops (Bergtold et al. 2012; Mishra et al. 2018). If farmers conducted one conservation practice on their cropland, they were more willing to use other conservation practices (Carlisle 2016). In addition, compared to owner-operators, renters, including cash-renters and share-renters, were less willing to adopt conservation practices, likely because many of the benefits of the practices were long-term (Soule, Tegene and Wiebe 2000). However, Carlisle (2016) indicated that the effect of land tenure factor was uncertain since some studies found that farmers with a higher percentage of rented land were less likely to use cover crops, while others found there was no significant correlation between the factor and conservation tillage adoption.

In terms of risk preferences, Boyer et al. (2018) developed a simulation model for the net present value (NPV) distribution of long-term investment in the use of cover crops and tillage systems, and found that farmers who were risk-neutral and profit-maximizing preferred conventional tillage and not using cover crops, while risk-averse farmers preferred no-till planting with no cover crops. Reimer et al. (2012) found that perceived risk is not a factor to limit farmers' adoption of agricultural best management practices. However, Burnett et al. (2018) and Bergtold et al. (2012) found that willingness to take

risks had a significant and positive impact on farmers' adoption of cover crops. In addition, farmers' risk preferences are correlated with their participation in crop insurance programs (Rosch 2017). Rosch (2017) indicated that American farmers were less likely to use crop insurance as a method to mitigate their risk, but rather as a stand-alone risky investment, which makes risk-averse farmers less likely to purchase crop insurance, while risk-seeking farmers were more likely to have crop insurance. Therefore, crop insurance could be a variable to measure a farmer's risk preference, and farmers who had crop insurance may be more willing to take risks and use cover crops.

Farmers who had more knowledge about the financial and on-farm benefits of conservation practices were more willing to adopt them (Carlisle 2016). Mishra et al. (2018) and Arbuckle and Roesch-McNally (2015) found that if farmers lack adequate knowledge about sustainable farming and are unfamiliar with related technologies, they are less likely to use cover crops. In addition, many farmers believe that more economic incentives, such as cost-share, more technical assistance, and helping them better understand the benefits of using cover crops are needed to improve and increase the adoption of cover crops (Reimer, Weinkauff and Prokopy 2012; Lee et al. 2018; Roesch-McNally et al. 2018). Therefore, research suggests that both policy and government educational programs can play an important role in influencing farmer decisions to adopt cover crops.

Economic Framework

Producer perceptions of the effects of using no-till and cover crops

The analysis of producer perceptions of conservation practices relative to their decision to adopt these practices draws on Rogers's adoption diffusion (A-D) model (Rogers 2003), which is used to describe, explain, and predict human behavior related to the adoption and diffusion of agricultural technologies (NRCS and USDA 2005). In the A-D model, a producer's decision to adopt an agricultural technology or practice is influenced by the following:

1. Information;
2. Knowledge of the practices;
3. Personal characteristics of the producer;
4. Farm/ranch characteristics;
5. Characteristics of the technology; and
6. Community characteristics (Rogers 2003; NRCS and USDA 2005).

In the process of deciding to adopt a new practice, information-seeking and information-processing activities are important factors that influence producer decision making since these activities give people a deeper understanding of a new idea and reduce their uncertainty about the advantages and disadvantages of the new idea (Rogers 2003).

In terms of knowledge of the practices, there are three types of knowledge in Rogers's (2003) innovation-decision process: awareness-knowledge, how-to-knowledge, and principles-knowledge. Rogers (2003) stated that awareness-knowledge is the

information that an innovation exists, how-to-knowledge includes information about how to use the innovation correctly, and principles-knowledge contains information about how an innovation works. If people lack principles-knowledge, they may be more likely to misuse or discontinue a practice. These principles and how-to-knowledge are considered to be the key variables in the adoption process, because if producers do not obtain a sufficient level of how-to-knowledge before the trial and adoption of the practice, they are likely to reject and/or discontinue adoption of the practice (Rogers 2003; Sahin 2006).

In addition to information and knowledge of innovative practices, Rogers (2003) also asserted that certain personal characteristics are positively associated with technology adoption, including number of years of formal education, above average income, willingness to take risks, and greater reliance on mass media. The farm characteristics that Rogers (2003) asserts are positively associated with technology adoption include large-scale farms, high gross farm sales, and owner operations (NRCS and USDA 2005).

Innovators and early adopters, who are young, have a high income, more education and large farm size, are more likely to obtain and use scientific information and knowledge about new agricultural technologies (Rogers 2003). Thus, based on Rogers' (2003) study, younger producers with more education, higher incomes, and larger farm size are expected to be more confident of the possible outcomes occurring from using no-till and cover crops.

The use of cover crops in Middle and West Tennessee

Economic thinking is based on a number of behavioral assumptions that are captured in rational choice theory. These assumptions are as follows:

1. Benefits and costs are considered before an action is undertaken;
2. The decision-maker has goals toward which the action is intended;
3. The unit of analysis is the decision-maker; and
4. The action is chosen based on values and utilities that maximize benefits or minimize costs (Zey 1997).

In addition, rational decisions are assumed to occur under scarcity of resources, institutional considerations, and sufficient, if not perfect, information. Farmers' decisions to adopt cover crops are modeled using McFadden's (1974) random utility framework. Farmers are assumed to maximize their expected utility. The decision to adopt cover crops (y) is 1 if the farmer adopts the cover crops; otherwise, the decision variable y is 0. Farmers are assumed to be willing to adopt cover crops when the expected utility of planting cover crops is greater than the expected utility of not planting, or when $U(y = 1) > U(y = 0)$. The utility function includes factors influencing the expected benefits and costs of adopting and not adopting the practice. Based on the literature review, producer demographics and farm characteristics are likely to impact adoption of cover crops. Therefore, this study analyzes how producer demographics and farm characteristics, such as age, education, farm income, and farm size, affect producers' use of cover crops.

Data

This study used responses to a 2017 survey of row crop producers in Middle and West Tennessee (Campbell 2018). The mailing addresses of land owners and corn, cotton, soybean, and wheat producers in Middle and West Tennessee who received a payment from the Farm Service Agency (FSA) between 2012 and 2016 were obtained from the FSA through a Freedom of Information Act request. Figure 1 in Appendix A shows a map of the counties included in the request. On January 26, 2017, these producers were sent a postcard notifying them that they would receive a mail survey. On February 8, 2017, a survey, postage-paid return envelope, a cover letter about the objectives of the survey, and an insert explaining the benefits and requirements of using winter cover crops, no-till, and irrigation water management were mailed to 5,184 producers. A reminder postcard was sent on February 17, 2017, and a second round of the survey was sent out on March 8, 2017. After subtracting those declining to participate, undeliverable addresses, and those who replied that the recipient does not farm, the survey sample was reduced to 3,841. A total of 346 survey responses were received, for a response rate of 9% (Campbell 2018).

The questionnaire consisted of six sections. The first section included questions related to acreage owned and leased, crop yields, and production costs. The second, third, and fourth sections contained questions about producers' experiences with and perceptions of no-till, cover crops, and irrigation management. The fifth section elicited the farmers' risk preferences. The sixth and final section of the survey focused on farmer

demographics, including education, age, and income. A copy of the survey instrument is attached as Appendix B.

A total of 86.8% of the respondents reported using no-till in 2016, while 29.1% of the respondents planted cover crops in 2016 (Table 1 in Appendix A). Respondents reported that total farmed acres were approximately 19,740 acres, of which 13,500 acres were planted in no-till, and 2,230 acres were planted in cover crops. Thus, for the survey respondents, the adoption rates in terms of acres were 68.4% for no-till and 11.3% for cover crops. In the 2017 Census of Agriculture (USDA 2019) for Middle and West Tennessee, the adoption rates in terms of acres were 65.5% for no-till and 7.5% for cover crops, while the adoption rates in terms of operations were 23.3% for no-till and 12.2% for cover crops. Therefore, in terms of acres or operations, the adoption rates for the survey respondents exceeded those reported in the 2017 Census of Agriculture. This finding could suggest some bias in the construction of the survey list frame, as farmers who received FSA payments may have been more likely to be no-till or cover crop users. It could also suggest response bias if those who used cover crops or no-till were more likely to complete and return the survey.

Appendix A Tables and Figures

Table 1. No-Till and Cover Crop Adoption Rates

Data		No-till	Cover crops
Survey in Middle & West TN	Respondents (n=302)	86.8%	29.1%
	Acres	68.4%	11.3%
2017 Census of Agriculture	U.S. (operations)	22.4%	12.3%
	U.S. (acres)	32.6%	4.8%
	Middle & West TN (operations)	23.3%	12.2%
	Middle & West TN (acres)	65.5%	7.5%

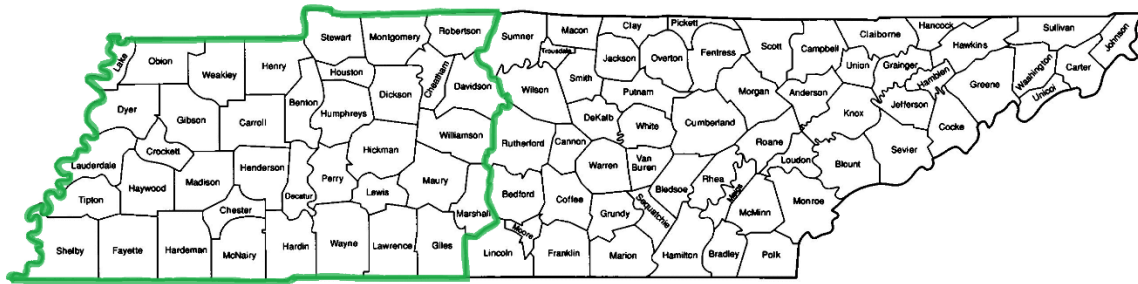


Figure 1. Map of Middle and West Tennessee Counties

Sources: <https://commons.wikimedia.org/wiki/>

Appendix B 2017 Middle and West Tennessee Row Crop Producer Survey

Middle & West Tennessee Row Crop Producer Survey

Thank you for participating in this survey!

Things to note as you begin:

- The survey is 5 pages. Please open the tri-fold booklet full to review all pages, including the back page of this booklet.
- The survey will take about 15 minutes to complete.
- Please refer to the information insert about no-till, irrigation, and cover crops.
- Please return your completed survey in the self-addressed, postage-paid envelope. If that envelope is missing, please mail the completed survey to Dr. Aaron Smith, 2621 Morgan Circle, Rm 302; Knoxville, TN 37996-4518.

YOUR FARM

Q1. Acres farmed in 2016 that were owned? _____ Acres Leased? _____ Acres

Q2. Non-irrigated and irrigated crop acres planted in 2016? Leave blank if crop not grown or irrigated.

Crop	Non-Irrigated Crop Acres	Irrigated Crop Acres
Corn		
Cotton		
Soybean		
Wheat		
Other: _____		

Q3. Your *lowest*, *average*, and *highest* yields since 2012? Leave blank if crop not grown or irrigated.

Crop	Non-Irrigated Yield			Irrigated Yield		
	Lowest	Average	Highest	Lowest	Average	Highest
Corn (bu/ac)						
Cotton (lbs/ac)						
Soybean (bu/ac)						
Wheat (bu/ac)						
Other: _____						

Q4. Excluding land rent cost only, check the box to indicate your most recent production costs per acre.

Crop	Non-irrigated field costs (\$/ac)				
Corn	☐ Less than \$199	☐ \$200-\$299	☐ \$300-\$399	☐ \$400-\$499	☐ Over \$500
Cotton	☐ Less than \$299	☐ \$300-\$399	☐ \$400-\$499	☐ \$500-\$599	☐ Over \$600
Soybean	☐ Less than \$99	☐ \$100-\$199	☐ \$200-\$299	☐ \$300-\$349	☐ Over \$350
Wheat	☐ Less than \$149	☐ \$150-\$199	☐ \$200-\$249	☐ \$250-\$299	☐ Over \$300
Crop	Irrigated field costs (\$/ac) – Leave blank if you did not irrigate				
Corn	☐ Less than \$299	☐ \$300-\$399	☐ \$400-\$499	☐ \$500-\$599	☐ Over \$600
Cotton	☐ Less than \$399	☐ \$400-\$499	☐ \$500-\$599	☐ \$600-\$699	☐ Over \$700
Soybean	☐ Less than \$199	☐ \$200-\$299	☐ \$300-\$399	☐ \$400-\$499	☐ Over \$500

Q5. Have you identified herbicide-resistant weeds on your farm? ☐ Yes → Year _____ ☐ No

QUESTIONS ABOUT NO-TILL*(SEE INFORMATION INSERT)***Q6.** Did you know the cost of using no-till may be partially reimbursed by the USDA?
☐ Yes
 ☐ No *(If NO, GO TO Question Q8)*
Q7. Have you ever received a cost-share payment for no-till planting? ☐ Yes ☐ No**Q8.** Do you plant with no-till? ☐ No☐ Yes → Year started? _____ 2016 no-till acres? _____ ac**Q9.** The expected cost of converting to no-till is \$25/ac. Would you convert acres to no-till if you were offered a cost share payment of \$[XXX]/ac?
☐ Yes, I would convert _____ ac
 ☐ No, I would not convert
 Q10. How likely is each of the following to occur from using **no-till** on your farm? (Check one box for each result)

← Less Likely---Chance of Occurring---More Likely →

	0-25%	25-49%	50/50%	51-75%	75-100%	No Idea
Increase yield	☐	☐	☐	☐	☐	☐
Reduce yield variability	☐	☐	☐	☐	☐	☐
Retain soil moisture	☐	☐	☐	☐	☐	☐
Reduce erosion	☐	☐	☐	☐	☐	☐
Reduce costs	☐	☐	☐	☐	☐	☐
Control weeds	☐	☐	☐	☐	☐	☐
Improve soil quality/health	☐	☐	☐	☐	☐	☐
Improve water quality	☐	☐	☐	☐	☐	☐
Increase management burden	☐	☐	☐	☐	☐	☐

QUESTIONS ABOUT COVER CROPS*(SEE INFORMATION INSERT)***Q11.** Did you know the costs of cover crop management may be partially reimbursed by the USDA?
☐ Yes
 ☐ No
 Q12. Did you plant cover crops in 2016?
☐ Yes *(GO TO Question Q13)*
☐ No, but I have previously used them *(GO TO Question Q14)*
☐ No, I have **never** used cover crops *(GO TO Question Q16)*
Q13. How many acres of cover crops did you plant in 2016? _____ acCover crops planted (list species): _____ *(GO TO Question Q15)*

Q14. If you used cover crops but stopped, why? (Check all that apply)

- ☐ Too expensive ☐ Made planting difficult ☐ Reduced yields
☐ Too complicated ☐ Tough to terminate ☐ Other _____

Q15. Have you ever received a cost-share payment for cover crops? ☐ Yes ☐ No

Q16. The expected cost of planting cover crops is \$77/ac. Would you plant cover crops next season if you were offered a cost share payment of \$[XXX]/ac?

- ☐ Yes, I would plant cover crops on _____ ac ☐ No, I would not plant cover crops

Q17. How likely is each of the following to occur from using **cover crops** on your farm? (Check one box for each result)

← Less Likely---Chance of Occurring---More Likely →

	0-25%	25-49%	50/50%	51-75%	75-100%	No Idea
Increase yield	☐	☐	☐	☐	☐	☐
Reduce yield variability	☐	☐	☐	☐	☐	☐
Retain soil moisture	☐	☐	☐	☐	☐	☐
Reduce erosion	☐	☐	☐	☐	☐	☐
Increase profit	☐	☐	☐	☐	☐	☐
Control weeds	☐	☐	☐	☐	☐	☐
Improve soil quality/health	☐	☐	☐	☐	☐	☐
Improve water quality	☐	☐	☐	☐	☐	☐
Increase planting difficulty	☐	☐	☐	☐	☐	☐

QUESTIONS ABOUT IRRIGATION WATER MANAGEMENT (SEE INFORMATION INSERT)

Q18. Did you know the costs of irrigation water management may be partially reimbursed by USDA?

- ☐ Yes ☐ No (If NO, GO TO Question Q20)

Q19. Have you ever received a cost-share payment for irrigation water management?

- ☐ Yes ☐ No

Q20. Do you irrigate? ☐ Yes → Year started: _____ ☐ No (If NO, GO TO Q29)

Q21. What is your primary water source for irrigation? (Check one)

- ☐ River/stream ☐ Farm pond ☐ Lake ☐ Well

Q22. If you pump from a well, how deep is your pump? _____ feet ☐ Don't know

Q23. How many acres do you irrigate using each type of system?

Center pivot _____ ac Furrow _____ ac Traveling gun _____ ac
Subsurface drip _____ ac Side roller _____ ac Other _____ ac

Q24. What power sources do you use to irrigate your crops? (Check all that apply)

☐ Electricity ☐ Diesel ☐ Natural gas ☐ Other _____

Q25. How do you determine when you need to irrigate? (Check all that apply)

☐ Water balance ☐ Soil moisture sensors ☐ Plant status ☐ Consultant
☐ Growth stage ☐ Neighbor irrigated ☐ A schedule ☐ Other _____

Q26. How much water (in/ac) do you usually apply when you irrigate? (Check one box for each crop)

Crop	Less than 0.25"	0.25"-0.50"	0.51-0.99"	1-1.49"	1.5-1.99"	2-2.49"	More than 2.49"
Corn	☐	☐	☐	☐	☐	☐	☐
Cotton	☐	☐	☐	☐	☐	☐	☐
Soybean	☐	☐	☐	☐	☐	☐	☐

Q27. The expected cost of using irrigation water management is \$25/ac. Would you use irrigation water management if you received a cost-share payment of \$[XXX]/ac?

☐ Yes, I would use it to manage _____ ac ☐ No, I would not use it

Q28. How likely is each of the following to occur from using **irrigation water management** on your farm? (Check one box for each result)

	← Less Likely---Chance of Occurring---More Likely →					No Idea
	0-25%	25-49%	50/50%	51-75%	75-100%	
Higher yields	☐	☐	☐	☐	☐	☐
Reduced yield variability	☐	☐	☐	☐	☐	☐
Increased profit	☐	☐	☐	☐	☐	☐
Securing an operating loan	☐	☐	☐	☐	☐	☐
Lower crop insurance costs	☐	☐	☐	☐	☐	☐

Q29. Which of the following pose challenges to irrigating on your farm? (Check all that apply)

☐ Field slope ☐ Field size ☐ Time and effort needed
☐ Field shape ☐ Installation expense ☐ Uncertain commodity prices
☐ Water quality ☐ Existing debt ☐ Uncertain energy costs
☐ Water availability ☐ Loan availability ☐ Other _____

RISK AND FARMING

Q30. Did you have crop insurance in 2016? ☐ Yes ☐ No

Q31. Indicate if you would or would not adopt *each* of the following technologies:

Farm Technology	-----IMPACTS ON YOUR FARM INCOME-----				Would you adopt this technology? (Please check one box in each row)	
	ADOPT the technology, and you have a 50/50 chance of:			DO NOT ADOPT, and your farm income is:		
	DECREASING your farm income by:	or	INCREASING your farm income by:		Yes, I would adopt	No, I would not adopt
A	-10%	or	+20%	Unchanged	☐	☐
B	-20%	or	+40%	Unchanged	☐	☐
C	-30%	or	+60%	Unchanged	☐	☐
D	-40%	or	+80%	Unchanged	☐	☐
E	-50%	or	+100%	Unchanged	☐	☐
F	-60%	or	+120%	Unchanged	☐	☐

Q32. Are you confident about your answers to the above question? ☐ Yes ☐ No ☐ Unsure

Q33. Are you confident this survey will influence farm programs? ☐ Yes ☐ No ☐ Unsure

GENERAL

Q34. Do you have a college degree (BS, BA, or equivalent)? ☐ Yes ☐ No

Q35. Year you were born? _____

Q36. Which category reflects your total farm and non-farm household income for 2016? (Check one box)

- ☐ Less than \$99,999 ☐ \$100,000 to \$299,999 ☐ \$300,000 to \$499,999
☐ \$500,000 to \$699,999 ☐ \$700,000 to \$999,999 ☐ \$1 million or greater

Q37. What percentage of your 2016 household income was from farming? _____ %

Please provide any comments about this survey:

-----END OF SURVEY-----

THANK YOU FOR PARTICIPATING! PLEASE RETURN THE SURVEY IN THE PRE-PAID ENVELOPE

CHAPTER II
**PRODUCER PERCEPTIONS OF THE EFFECTS OF USING NO-
TILL AND COVER CROPS**

Methods

Means comparison of farmer perceptions

Figures 2 and 3 in Appendix C show the survey questions used to elicit farmer perceptions of using no-till and cover crops. These questions elicit producer perceptions of nine possible outcomes from using no-till and cover crops: increasing yield, reducing yield variability, retaining soil moisture, reducing erosion, reducing costs, controlling weeds, improving soil quality/health, improving water quality, and increasing management burden. Comparing mean perceptions of the likelihood of each result occurring provides insight into farmer perceptions of the effects of adopting these practices. Similarly, comparing differences in means across identifiable groups of respondents on the basis of their experience with these practices provides insight into how these perceptions influence adoption and/or how perceptions are influenced by experience.

Two-sample t-tests are used to compare differences in means across groups. For analysis of the mean perceptions of the effects of using no-till, respondents are divided into two groups: users and non-users. No-till users are respondents who planted with no-till in 2016, and non-users are respondents who did not plant with no-till in 2016. For analysis of the mean perceptions of using cover crops, respondents are also divided into users and non-users. Cover crop users are respondents who planted with cover crops in 2016, and non-users are respondents who did not plant with cover crops in 2016. In addition, cover crop non-users are divided into never users and abandoners. Never users are respondents who had never used cover crops, and abandoners are respondents who

had previously used cover crops but did not in 2016. ³Definitions of these groups are also provided in Table 2 in Appendix C.

Farmer perceptions of the effects of using no-till

The variables representing respondent perceptions of the effects of using no-till are coded as one for respondents who chose 0-25% to the likelihood of outcome occurring from no-till, as two for those who chose 25-49%, as three for those who chose 50/50%, as four for those who chose 51-75%, and as five for those who chose 75-100%. However, those who chose “No Idea” in response to the questions on the likelihood of the effects are excluded from the comparison of the mean likelihood.

No-till users are expected to have more positive perceptions of the effects of using no-till than non-users, as those who use the practice are more likely to believe the effects, or those who believe that no-till has positive effects are more likely to use no-till. Thus, the null and alternative hypotheses for the comparison of the mean likelihood of each outcome occurring between no-till users and non-users are specified as:

$$(1) H_0: \mu_{ntuser,i} \leq \mu_{ntnon,i} \text{ and } H_1: \mu_{ntuser,i} > \mu_{ntnon,i} ,$$

where $\mu_{ntuser,i}$ and $\mu_{ntnon,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across the user and non-user groups, respectively. One-tailed tests are used in hypothesis tests. The definitions of the variables are provided in Table 3 in Appendix C.

To determine whether there is a significant difference between mean no-till user and non-user awareness of the likelihood of each outcome occurring, the variable

³ No similar distinction can be made among no-till non-users as the survey did not ask no-till non-users about prior use of no-till.

awareness is coded as zero for respondents who chose “No Idea” in response to the questions on the likelihood of occurrence and as one for those who chose one of the percentage response options. Since users are expected to have more information on the effects of the practice than non-users, the null and alternative hypotheses are specified as:

$$(2) H_0: \mu_{ntuser_aw,i} \leq \mu_{ntnon_aw,i} \text{ and } H_1: \mu_{ntuser_aw,i} > \mu_{ntnon_aw,i} ,$$

where $\mu_{ntuser_aw,i}$ and $\mu_{ntnon_aw,i}$ represent the mean values of the awareness variable of the i^{th} outcome occurring across users and non-users, respectively (Table 3 in Appendix C). One-tailed tests are used in hypothesis tests.

Farmer perceptions of the effects of using cover crops

The variables representing respondent perceptions of the effects of using cover crops are coded the same as for no-till. In terms of cover crops, those who planted with cover crops in 2016 are expected to be more likely to believe the practice has positive effects than those who did not, and thus, the null and alternative hypotheses for the comparison of mean likelihood of each outcome occurring between users and non-users are specified as:

$$(3) H_0: \mu_{ccuser,i} \leq \mu_{ccnon,i} \text{ and } H_1: \mu_{ccuser,i} > \mu_{ccnon,i} ,$$

where $\mu_{ccuser,i}$ and $\mu_{ccnon,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across the user and non-user groups, respectively. One-tailed tests are used in hypothesis tests. The definitions of the variables are provided in Table 3 in Appendix C.

On the other hand, to compare mean values of cover crop user and non-user awareness of the likelihood of each outcome occurring, the variable *awareness* is coded

as the same as for no-till. Cover crop users are expected to have more information on the effects of the practice than non-users, so the null and alternative hypotheses are specified as:

$$(4) H_0: \mu_{ccuser_aw,i} \leq \mu_{ccnon_aw,i} \text{ and } H_1: \mu_{ccuser_aw,i} > \mu_{ccnon_aw,i} ,$$

where $\mu_{ccuser_aw,i}$ and $\mu_{ccnon_aw,i}$ represent the mean values of the awareness variable of the i^{th} outcome occurring across users and non-users, respectively (Table 3 in Appendix C). One-tailed tests are used in hypothesis tests.

In addition, if cover crops truly do have these effects, then those who had used them should be more likely to believe the effects are more likely to occur than those who have never used the practices. However, it could be that those who have abandoned the practice did so because they did not realize these effects. Therefore, there would be no significantly different mean perceptions of the likelihood of each result occurring from cover crops between cover crop never users and abandoners. The null and alternative hypotheses are specified as:

$$(5) H_0: \mu_{aban,i} = \mu_{never,i} \text{ and } H_1: \mu_{aban,i} \neq \mu_{never,i} ,$$

where $\mu_{aban,i}$ and $\mu_{never,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across abandoners and never users, respectively. Two-tailed tests are used in hypothesis tests. The definitions of the variables are provided in Table 3 in Appendix C.

However, those who have experiences in cover crops are expected to have higher levels of awareness of effects of the practice than those who had never used them, and thus, the null and alternative hypotheses are specified as:

$$(6) H_0: \mu_{aban_aw,i} \leq \mu_{never_aw,i} \text{ and } H_1: \mu_{aban_aw,i} > \mu_{never_aw,i} ,$$

where $\mu_{aban_aw,i}$ and $\mu_{never_aw,i}$ represent the mean values of the awareness variable of the i^{th} outcome occurring across abandoners and never users, respectively (Table 3 in Appendix C). One-tailed tests are used in hypothesis tests.

Those who had previously used cover crops but did not in 2016 may be because they did not realize the effects of using the practice. Thus, in terms of users and abandoners, users are expected to be more likely to believe the effects occurring from cover crops than abandoners. The null and alternative hypotheses are specified as:

$$(7) H_0: \mu_{ccuser,i} \leq \mu_{aban,i} \text{ and } H_1: \mu_{ccuser,i} > \mu_{aban,i} ,$$

where $\mu_{ccuser,i}$ and $\mu_{aban,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across the users and abandoners, respectively. One-tailed tests are used in hypothesis tests. The definitions of the variables are provided in Table 3 in Appendix C.

Farmer perceptions of the common effects of using no-till and cover crops

Comparing farmer mean perceptions of the likelihood of each outcome that is common to both no-till and cover crops provides insight into farmers' view on which practice is more likely to lead to the effects than the other. Paired t-tests are used to compare differences in the mean values across all respondents. The variables representing respondent perceptions of the effects of using no-till and cover crops are coded the same as for no-till.

Given that the adoption rate of no-till in terms of respondents is much higher than that of cover crops, respondents are expected to have more favorable perceptions of the

likelihood of each outcome occurring from the use of no-till than from the use of cover crops. Thus, the null and alternative hypotheses are specified as:

$$(8) H_0: \mu_{nt,i} \leq \mu_{cc,i} \text{ and } H_1: \mu_{nt,i} > \mu_{cc,i} ,$$

where $\mu_{nt,i}$ and $\mu_{cc,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across no-till and cover crops, respectively. One-tailed tests are used in hypothesis tests. The definitions of the variables are provided in Table 3 in Appendix C.

Similarly, respondents are also expected to be more confident of their knowledge of the effects of no-till than cover crops. The mean values of respondent awareness can be compared across the practices for each outcome and all respondents, and the null and alternative hypotheses are specified as:

$$(9) H_0: \mu_{nt_aw,i} \leq \mu_{cc_aw,i} \text{ and } H_1: \mu_{nt_aw,i} > \mu_{cc_aw,i} ,$$

where $\mu_{nt_aw,i}$ and $\mu_{cc_aw,i}$ represent the mean values of the awareness variable of the i^{th} outcome occurring across no-till and cover crops, respectively, for all respondents (Table 3 in Appendix C). One-tailed tests are used in hypothesis tests.

In addition, when comparing the mean likelihood of each outcome between no-till users and cover crop users, they are expected to have no significant difference in the mean likelihoods except for controlling weeds, as those who use the practice are likely to believe the effects, or those who believe that the practice has positive effects are likely to use it. However, cover crop users are expected to have a higher mean likelihood of controlling weeds than no-till users, as cover crops can suppress weed growth. The null and alternative hypotheses are specified as:

$$(10) H_0: \mu_{ntuser,i} = \mu_{ccuser,i} \text{ and } H_1: \mu_{ntuser,i} \neq \mu_{ccuser,i} ,$$

where $\mu_{ntuser,i}$ and $\mu_{ccuser,i}$ represent the mean values for the likelihood of the i^{th} outcome occurring across no-till users and cover crop users, respectively (Table 3 in Appendix C). Two-tailed tests are used in hypothesis tests.

Farmer perceptions models

To analyze the factors influencing farmer perceptions of the likelihood of each of these outcomes occurring, the responses to farmer perceptions of using no-till and cover crops are used as dependent variables. In Rogers' (2003) adoption diffusion model, innovators and early adopters are more likely to obtain knowledge and information about new practices, and personal characteristics of the producers and farm characteristics are correlated with adoption of the practices. Rogers (2003) and Prokopy et al. (2008) indicated that the characteristics of innovators or early adopters are those who are young, wealthy, have more education, and have large farm size. Therefore, age (*age* and *age*²), education level (*edu*), farm income (*income* and *income*²), and total farmed acres (*size* and *size*²) are used as independent variables. Since producer experiences might influence their perceptions of using the practices, whether the producer had identified herbicide-resistant weeds or not (*weeds*), planted no-till (*nt*) or cover crops (*cc*) in 2016 or not, and used irrigation or not (*irrigation*) are included in the model. However, in the farmer perceptions of using no-till equation, whether farmers planted no-till in 2016 (*nt*) is not used as an independent variable, because the variable *nt* may be an endogenous variable, and the result of adopting or not may be influenced by their perceptions of no-till. Similarly, whether farmers planted cover crops in 2016 (*cc*) is not used as an independent variable in the farmer perceptions of using cover crops equation.

In addition, policy may also influence producer perceptions of the practices, as producers who know about or have received a cost-share payment for the practices may obtain more information from governments or have experience of the practices. Thus, whether the producer both knew about and had ever received a cost-share payment for no-till (*yy*) or for cover crops (*cyy*), and whether the producer knew about but had not ever received a cost-share payment for no-till (*yn*) or for cover crops (*cyn*) are used as independent variables. Using ordered probit models to estimate the relationship between farmer perceptions of the likely outcomes of adopting the practices and the independent variables, the equations of farmer perceptions of the effects of using no-till and cover crops are specified as:

$$(11) y_{nt,i}^* = \alpha_0 + \alpha_1 age_i + \alpha_2 age_i^2 + \alpha_3 edu_i + \alpha_4 income_i + \alpha_5 income_i^2 + \alpha_6 size_i + \alpha_7 size_i^2 + \alpha_8 weeds_i + \alpha_9 cc_i + \alpha_{10} irrigation_i + \alpha_{11} yy_i + \alpha_{12} yn_i + \varepsilon_{nt,i} ,$$

$$(12) y_{cc,i}^* = \beta_0 + \beta_1 age_i + \beta_2 age_i^2 + \beta_3 edu_i + \beta_4 income_i + \beta_5 income_i^2 + \beta_6 size_i + \beta_7 size_i^2 + \beta_8 weeds_i + \beta_9 nt_i + \beta_{10} irrigation_i + \beta_{11} cyy_i + \beta_{12} cyn_i + \varepsilon_{cc,i} ,$$

where $y_{nt,i}^*$ represents farmer perceptions of the likelihood of an outcome occurring as a result of adopting no-till, and $y_{cc,i}^*$ represents farmer perceptions of the likelihood of an outcome occurring as a result of adopting cover crops. The definitions of the explanatory variables and the coding of dependent variables are provided in Table 4 in Appendix C. Summary statistics are provided in Tables 5 and 6 in Appendix C.

An alternative specification of the dependent variables creates a single variable to represent a respondent's relative perceptions for no-till and cover crops. This variable groups the respondents into three categories for each of the possible outcomes that are common to both no-till and cover crops. The variable *perception* is coded as one for respondents who believed the outcome has a lower likelihood of occurring with the adoption of no-till than with the adoption of cover crops, as two for those who believed the outcome has an equal likelihood of occurring with the adoption of no-till and with the adoption of cover crops, and as three for those who believed the outcome has a higher likelihood of occurring with the adoption of no-till than with the adoption of cover crops (Table 4 in Appendix C).

The resulting model is specified as:

$$(13) y_{nc,i}^* = \gamma_0 + \gamma_1 age_i + \gamma_2 age_i^2 + \gamma_3 edu_i + \gamma_4 income_i + \gamma_5 income_i^2 + \gamma_6 size_i + \gamma_7 size_i^2 + \gamma_8 weeds_i + \gamma_9 irrigation_i + \gamma_{10} yy_i + \gamma_{11} yn_i + \gamma_{12} cyy_i + \gamma_{13} cyn_i + \varepsilon_{nc,i} ,$$

where $y_{nc,i}^*$ represents the three categories for each common outcome occurring from both no-till and cover crops. The definitions of the explanatory variables are provided in Table 4 in Appendix C.

A Priori Hypothesis about Variables

Table 7 in Appendix C provides the predicted signs of the coefficients for the explanatory variables for the equations of farmer perceptions of no-till and cover crops. Rogers (2003) concluded that younger producers with higher incomes were more likely to innovate and be willing to get and have close contact with scientific information. Therefore, the coefficient for the variable *age* is hypothesized to have a negative sign and the variable *income* is hypothesized to have a positive sign when the dependent variables are increasing yield, reducing yield variability, retaining soil moisture, reducing erosion, reducing costs, controlling weeds, improving soil quality/health, and improving water quality. The square terms of age and farm income (age^2 and $income^2$) are also used as independent variables in the models to see their patterns, and the coefficients for both of them are expected to be negative.

Prokopy et al. (2008) indicated that the farmer education level and diversity of farm operation have a positive relationship with agricultural best management practice adoption, perhaps because producers with more education can more easily obtain information and ideas, and producers with more diverse farm operations may be more willing to try new practices. Thus, the variables *edu*, *nt*, *cc*, and *irrigation* are expected to be positively correlated with farmers' beliefs in the likelihood of the potential benefits of no-till and cover crops occurring. The coefficient for the variable *size* is expected to be positive since large farm size would have greater economies of scale (Prokopy et al. 2008). The square term of size ($size^2$) is also used as an explanatory variable in the models to see its patterns, and the coefficient for $size^2$ is expected to be negative.

Farmers who knew about cost-share for no-till or cover crops are likely to be more aware of the practices, and farmers who had received a cost-share payment for no-till or cover crops had already used them, so they may be more confident that using no-till and cover crops can bring benefits. Therefore, the coefficients of the variables yy , yn , cyy , and cyn are hypothesized to have positive signs. However, hypothesis about the variable *weeds* is uncertain.

For the model grouping relative farmer perceptions of the likelihood of the outcomes occurring given no-till and cover crop adoption into three categories, there is not enough information to provide *a priori* expectations about the impact of farmer demographics and farm characteristics on differences in farmer perceptions.

Results

Distribution of respondent perceptions

Respondents believed that the most likely outcome to occur from adopting no-till or cover crops was to reduce soil erosion, followed by improving soil quality/health (Figures 4 and 5 in Appendix C). Approximately, 64.98% of respondents believed that using no-till was more likely than not to reduce soil erosion, while 58.3% believed the same of cover crops. 60.31% of respondents believed that using no-till can improve soil quality/health, while 53.28% believed the same of cover crops.

A majority of respondents believed that the adoption of no-till would improve soil quality/health (60.31%), retain soil moisture (60%), and improve water quality (57.67%). Similarly, a majority of respondents believed the use of cover crops would improve soil

quality/health (53.28%), and improve water quality (52.74%), while a minority of respondents believed using cover crops would retain soil moisture (48.15%).

On the other hand, respondents believed that it was least likely that using no-till would reduce yield variability, while they believed that using cover crops was least likely to increase profit. Approximately, 29.82% of respondents believed that using no-till was less likely to reduce yield variability, followed by increasing yield and controlling weeds. Approximately, 28.14% of respondents believed that using cover crops was less likely to increase profit, followed by increasing yield and decreasing yield variability.

In terms of those who chose “No Idea” in response to the questions on the likelihood of occurrence, respondents had less information that using no-till would decrease yield variability, increasing yield and management burden. They also had less information that using cover crops would decrease yield variability, increase profit and yield.

Means comparison of farmer perceptions

Farmer perceptions of the effects of using no-till

The statistical test results of no-till user and non-users are provided in Table 8 in Appendix C, which shows whether the mean likelihood of an outcome occurring for no-till users is significantly higher than non-users. The sample size of no-till non-users was small since the non-adoption rate in terms of respondents was only 13.2% of the total 302 respondents. In terms of mean likelihood of an outcome occurring, on average, users were more likely to believe no-till adoption would lead to all of the possible outcomes other than increase management burden than non-users. Thus, no-till users were more

confident of the benefits of using no-till than non-users. Similarly, in terms of mean awareness, no-till users were more likely to have an opinion on the likelihood of all of the different possible outcomes occurring as a result of the adoption of no-till than non-users (Table 8 in Appendix C).

Farmer perceptions of the effects of using cover crops

Table 9 in Appendix C shows the statistical test results of the mean likelihood of an outcome occurring for cover crop users and non-users. Cover crop users were more likely to believe adopting cover crops would lead to all of the possible outcomes except for increasing management burden than non-users. Cover crop users were also more likely to have an opinion on the likelihood of all of the different possible outcomes occurring as a result of the adoption of cover crops than non-users.

On the other hand, cover crop abandoners and never users were not significantly different in mean perceptions of the likelihood of each outcome occurring as a result of the adoption of cover crops. However, in terms of mean awareness, cover crop abandoners had higher levels of awareness of all of the effects of the practice than never users (Table 10 in Appendix C). In addition, when comparing cover crop user and abandoner perceptions mean likelihood of each outcome occurring, cover crop users were more likely to have positive perceptions of the likelihood of some but not all of the effects than abandoners (Table 11 in Appendix C). Specifically, compared to abandoners, users, on average, believed cover crop adoption was more likely to increase yield, reduce yield variability and erosion, retain soil moisture, improve soil and water quality, and

control weeds. There were no significant differences in the mean likelihoods between users and abandoners for reducing costs and increasing management burden.

Farmer perceptions of the common effects of using no-till and cover crops

The statistical test results of farmer perceptions and awareness of the likelihood of each outcome occurring from using no-till and cover crops across all respondents are provided in Table 12 in Appendix C. On average, respondents believed that no-till is more likely to increase yield, retain soil moisture, reduce erosion and costs, and improve soil and water quality than cover crops, but less likely to control weeds than cover crops. Similarly, respondents were more likely to have an opinion on the likelihood of the benefits of adopting no-till than cover crops in terms of retaining soil moisture, reducing erosion and costs, controlling weeds, and improving soil quality. In addition, in terms of no-till users and cover crop users, there were no significant differences in the mean likelihoods of all of the effects other than controlling weeds (Table 13 in Appendix C). On average, cover crop users were more confident that cover crop use would control weeds than no-till users were that no-till use would control weeds.

Farmer perceptions models

Farmer perceptions models of using no-till

This study used ordered probit models to estimate factors influencing farmer perceptions of the effects of using no-till and cover crops. Table 14 in Appendix C shows the factors that affect farmer perceptions of the effects of using no-till in Middle and West Tennessee. In terms of farmer demographics, the variable *edu* had a positive impact on the effects of using no-till, including increasing yield, reducing yield variability and

costs, controlling weeds, improving soil quality/health and water quality. The coefficient for the variable *income* was significant and positive only for reducing costs. The variable *age* was positively correlated with the effects of the use of no-till on reducing erosion, improving soil quality/health and water quality, and the coefficient for *age*² was negative, so the pattern was a concave curve. In terms of farmer experience, the variable *irrigation* was positively correlated with all of the possible outcomes occurring from using no-till except for increasing yield, reducing yield variability, and increasing management burden. The coefficient for the variable *cc* was significant and positive for retaining soil moisture, while the coefficients for the variables *size*² and *yn* were significantly negative for improving water quality and improving soil quality/health, respectively. However, the variables *income*², *size*, *weeds*, and *yy* were not statistically significant at a 10% level.

In summary, on average, the factors that education level and the use of irrigation were more likely to influence farmer perceptions of the likelihood of the effects of using no-till. Respondents with more education and irrigation experience were more likely to have positive perceptions of the effects of the use of no-till. However, contrary to the priori hypothesis, age was positively correlated with the likelihood of some outcomes occurring from no-till, which may be due to the widespread adoption of no-till in this region for a number years. Farm income, using cover crops, and knowing about a cost-share payment for no-till had some impacts on farmers' opinions of the effects of using no-till, but farm size, whether farmers had identified herbicide-resistant weeds, and whether they both knew about and had received a cost-share payment did not affect farmer perceptions of the effects no-till adoption.

Farmer perceptions models of using cover crops

The results of the factors that influence farmer perceptions of using cover crops are provided in Table 15 in Appendix C. The coefficient for *edu* was not significant for the likelihood of all of the possible outcomes occurring from cover crop adoption. The coefficients for *income* and *income*² were negative and positive, so the pattern was a convex curve. The variable *age* was significantly positive and *age*² was significantly negative, meaning farmer age was positively correlated with the effects of the use of cover crops on retaining soil moisture, reducing erosion, and improving water quality, and the pattern was a concave curve. The variable *irrigation* had a positive impact on the effects of using cover crops for increasing yield. The variable *size* had a positive impact on the likelihood of reducing erosion, while the coefficient for *size*² was negative. The variable *weeds* was positively correlated with the likelihood of increasing planting difficulty. The coefficient for *nt* was significant and positive for all of the possible outcomes occurring from using cover crops except for reducing yield variability and reducing costs. The coefficient for *cyn* was negative for increasing planting difficulty, while non-significant for all of the possible benefits of the use of cover crops. The variable *cyy* had a positive impact on all of the possible outcomes occurring from using cover crops except for retaining soil moisture and increasing planting difficulty.

In summary, on average, the use of no-till and producers both knowing about and having received a cost-share payment for cover crops were the variables that most commonly influence farmer perceptions of the effects of using cover crops. Respondents who used no-till or both knew about and had received a cost-share payment for cover

crops were more likely to have positive attitudes of the benefits of cover crop adoption. In addition, contrary to the previous studies, age was positively correlated with the likelihood of retaining soil moisture, reducing erosion, and improving water quality occurring from using cover crops.

Farmer group perceptions models of using no-till and cover crops

Table 16 in Appendix C shows the factors that influence farmer group perceptions of the possible outcomes that are common to both no-till and cover crop adoption. The coefficient for *edu* was significant and positive for farmer perceptions of the likelihood of all of the effects other than retaining soil moisture, reducing erosion, controlling weeds and increasing planting difficulty occurring from both using no-till and cover crops. The coefficient for *size* and *size*² were negative and positively, respectively, for reducing yield variability and controlling weeds. The variable *weeds* had positive impact on farmer perceptions of the likelihood of increasing yield, reducing yield variability, and improving water quality. The variable *irrigation* had negative impact on farmer perceptions of the likelihood of controlling weeds. In terms of cost-share payment, *cyy* were significantly negative for improving soil and water quality, while *cyn* were significantly positive for reducing yield variability. However, the coefficients for *age*, *age*², *income*, *income*², *yy* and *yn* were not statistically significant at a 10% level.

In summary, education level and having identified herbicide-resistant weeds were the factors that most commonly affect farmer perceptions of the effects of using no-till and cover crops. Respondents with more education and who have identified herbicide-resistant weeds were more likely to believe either the uses of no-till and cover crops have

equal likelihood to cause the outcomes, or the use of no-till is more likely to cause the outcomes than the use of cover crops. However, those who both knew about and had received a cost-share payment for cover crops were less likely to believe that the use of no-till is more likely to cause the outcomes than the use of cover crops. In addition, there were none significant variables to influence producer perceptions of the likelihood of retaining soil moisture, reducing erosion, and increasing planting difficulty of using no-till and cover crops.

Conclusions

The adoption rates of no-till and cover crops in the U.S. are relatively low (USDA 2019). A failure to understand the influence of adopting no-till or cover crops may be the reason why producers do not use them. Lack of sufficient knowledge about conservation practices or sustainable farming, as well as unfamiliarity with related technologies, would make farmers be less likely to adopt them (Mishra et al. 2018). Therefore, a better understanding of farmers' perceptions or opinions and the use of no-till and cover crop planting could help the government to design educational programs and policies to promote the adoption of the practices.

This study utilized a 2017 survey of row crop producers in Middle and West Tennessee to analyze how farmers in the region think about using no-till and cover crops. Previous studies indicated that no-till and cover crop planting can help reduce soil erosion, improve water quality, improve soil quality, and control weeds, while the impact of the practices on crop yield are uncertain (Uri 2000; Balkcom et al. 2007; Daryanto et al. 2018; SARE and CTIC 2016; Lira and Tyner 2018). The results from the survey

showed that respondents believed the most likely outcome occurring from using no-till and cover crops was reducing soil erosion, followed by improving soil quality/health. On the other hand, they were less likely to believe that adopting no-till would reduce yield variability, increase yield, or control weeds. They also did not believe that adopting cover crops was likely to increase profit, increase yield, or reduce yield variability. Although prior research has suggested that yield was more stable when adopting no-till and cover crops, farmers in Middle and West Tennessee were less likely to believe that using these practices would reducing yield variability. Thus, this is a difference between producer perceptions of the effects of no-till and cover crops and what previous research suggests these effects are.

According to the statistical test results, no-till users were more confident of and more likely to have an opinion on the likelihood of the effects of using no-till than non-users. Similarly, cover crop users were more likely to believe and have an opinion on the likelihood of the possible outcomes occurring from adopting cover crops than non-users. Cover crop abandoners and never users did not have a significant difference in mean perceptions of the likelihood of each result occurring from cover crops, while abandoners had higher levels of awareness of all of the effects of using cover crops than never users. Compared to abandoners, cover crop users had more positive perceptions of the outcomes occurring from the use of cover crops. In addition, respondents believed that no-till was more likely to have some effects than cover crops, but less likely to control weeds than cover crops. On average, cover crop users are likely to believe that the use of cover crops will control weeds than no-till users are likely to believe no-till use will control weeds.

For farmer perceptions of the effects of using no-till, respondents with more education and irrigation experience were more likely to have positive perceptions of the effects of using no-till. However, age was positively correlated with the likelihood of some outcomes occurring from no-till. For farmer perceptions of the effects of using cover crops, respondents who used no-till or both knew about and had received a cost-share payment for cover crops were more likely to have positive attitudes of the benefits of the use of cover crops. In terms of producer perceptions of common outcomes occurring from both no-till and cover crops, respondents who have a college degree or had identified herbicide-resistant weeds were more likely to believe either the uses of no-till and cover crops have equal likelihood to cause the outcomes, or the use of no-till is more likely to cause the outcomes than the use of cover crops. However, respondents who both knew about and had received a cost-share payment for cover crops were less likely to believe that using no-till is more likely to cause the outcomes than using cover crops. Therefore, these findings can enable a better understanding of farmers' opinions of these practices and the factors that influence their perceptions, and improve the design of programs to promote their adoption.

Appendix C Tables and Figures

Table 2. Definition of Groups of No-Till and Cover Crops

	Group	Description
No-Till	User (<i>ntuser</i>)	Respondent used no-till in 2016
	Non-User (<i>ntnon</i>)	Respondent did not with no-till in 2016
Cover Crops	User (<i>ccuser</i>)	Respondent used cover crops in 2016
	Non-User (<i>ccnon</i>)	Respondent did not use cover crops in 2016
	└ Never User (<i>ccnever</i>)	Respondent had never used cover crops
	└ Abandoner (<i>aban</i>)	Respondent had previously used cover crops but did not in 2016

Table 3. Definition of Variables Used in Means Comparison of Farmer Perceptions and Awareness

Variable	Description
<i>Likelihood of outcome occurring (= 1 if 0-25%, = 2 if 25-49%, = 3 if 50/50%, = 4 if 51-75%, and = 5 if 75-100%)</i>	
$\mu_{ntuser,i}$	Mean likelihood of outcome i occurring among no-till users
$\mu_{ntnon,i}$	Mean likelihood of outcome i occurring among no-till non-users
$\mu_{ccuser,i}$	Mean likelihood of outcome i occurring among cover crop users
$\mu_{ccnon,i}$	Mean likelihood of outcome i occurring among cover crop non-users
$\mu_{never,i}$	Mean likelihood of outcome i occurring among cover crop never users
$\mu_{aban,i}$	Mean likelihood of outcome i occurring among cover crop abandoners
$\mu_{cc,i}$	Mean likelihood of outcome i occurring from using no-till among all respondents
$\mu_{nt,i}$	Mean likelihood of outcome i occurring from using cover crops among all respondents
<i>Awareness (= 0 if answered "No Idea"; otherwise = 1)</i>	
$\mu_{ntuser_aw,i}$	Mean awareness of likelihood of outcome i occurring among no-till users
$\mu_{ntnon_aw,i}$	Mean awareness of likelihood of outcome i occurring among no-till non-users
$\mu_{ccuser_aw,i}$	Mean awareness of likelihood of outcome i occurring among cover crop users
$\mu_{ccnon_aw,i}$	Mean awareness of likelihood of outcome i occurring among cover crop non-users
$\mu_{never_aw,i}$	Mean awareness of likelihood of outcome i occurring among cover crop never users
$\mu_{aban_aw,i}$	Mean awareness of likelihood of outcome i occurring among cover crop abandoners
$\mu_{nt_aw,i}$	Mean awareness of likelihood of outcome i occurring from using no-till among all respondents
$\mu_{cc_aw,i}$	Mean awareness of likelihood of outcome i occurring from using cover crops among all respondents

Table 4. Definition of Dependent Variables and Explanatory Variables

Variable	Description
<i>Dependent Variables</i>	
$y_{nt,i}^*$	Likelihood of outcome i occurring from use of no-till = 1 if 0-25%, = 2 if 25-49%, = 3 if 50/50%, = 4 if 51-75%, and = 5 if 75-100%
$y_{cc,i}^*$	Likelihood of outcome i occurring from use of cover crops = 1 if 0-25%, = 2 if 25-49%, = 3 if 50/50%, = 4 if 51-75%, and = 5 if 75-100%
$y_{nc,i}^*$	Three categories for outcome i that are common to both no-till and cover crops = 1 if respondent thinks no-till adoption has lower likelihood of the change occurring than cover crop adoption, = 2 if respondent thinks no-till adoption has equal likelihood of the change occurring than cover crop adoption, = 3 if respondent thinks no-till adoption has a higher likelihood of the change occurring than cover crop adoption
<i>Independent Variables</i>	
<i>age</i>	Age of farmer (years)
<i>age</i> ²	Square term of farmer age (100 years)
<i>edu</i>	= 1 if respondent has a college degree; otherwise = 0
<i>income</i>	Total farm income in 2016 (\$1,000)
<i>income</i> ²	Square term of farm income in 2016 (\$10 billion)
<i>size</i>	Acres farmed in 2016 (100 acres)
<i>size</i> ²	Square term of acres farmed in 2016 (10 million)
<i>weeds</i>	= 1 if respondent has identified herbicide-resistant weeds on farm; otherwise = 0
<i>nt</i>	= 1 if respondent planted no-till in 2016; otherwise = 0
<i>cc</i>	= 1 if respondent planted cover crops in 2016; otherwise = 0
<i>irrigation</i>	= 1 if respondent irrigated in 2016; otherwise = 0
<i>yy</i>	= 1 if respondent knew about cost-share for no-till and have ever received a cost-share payment for no-till planting; otherwise = 0
<i>yn</i>	= 1 if respondent knew about cost-share for no-till, but have not ever received a cost-share payment for no-till planting; otherwise = 0
<i>cyy</i>	= 1 if respondent knew about cost-share for cover crops and have ever received a cost-share payment for cover crop planting; otherwise = 0
<i>cyn</i>	= 1 if respondent knew about cost-share for cover crops but have not ever received a cost-share payment for cover crop planting; otherwise = 0

Table 5. Summary Statistics of Explanatory Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	N
<i>age</i>	63.51	14.15	21	98	318
<i>age</i> ²	42.34	17.25	4.41	96.04	318
<i>edu</i>	0.41	0.49	0	1	329
<i>income</i>	95.77	191.73	0	1100	296
<i>income</i> ²	4.21	17.33	0	121	296
<i>size</i>	5.71	11.64	0	100	346
<i>size</i> ²	0.17	0.75	0	100	346
<i>weeds</i>	0.69	0.46	0	1	253
<i>nt</i>	0.87	0.34	0	1	302
<i>cc</i>	0.29	0.46	0	1	302
<i>irrigation</i>	0.15	0.36	0	1	275
<i>yy</i>	0.05	0.21	0	1	346
<i>yn</i>	0.12	0.33	0	1	346
<i>cyy</i>	0.15	0.36	0	1	346
<i>cyn</i>	0.16	0.37	0	1	346

Table 6. Summary Statistics of Dependent Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	N
$y_{nt,i}^*$					
<i>Increase yield</i>	2.97	1.41	1	5	200
<i>Reduce yield variability</i>	2.83	1.37	1	5	172
<i>Retain soil moisture</i>	3.81	1.33	1	5	232
<i>Reduce erosion</i>	4.01	1.31	1	5	239
<i>Reduce costs</i>	3.31	1.42	1	5	219
<i>Control weeds</i>	3.14	1.32	1	5	212
<i>Improve soil quality</i>	3.88	1.28	1	5	228
<i>Improve water quality</i>	3.94	1.25	1	5	215
<i>Increase management burden</i>	3.20	1.44	1	5	200
$y_{cc,i}^*$					
<i>Increase yield</i>	2.84	1.30	1	5	191
<i>Reduce yield variability</i>	2.83	1.27	1	5	166
<i>Retain soil moisture</i>	3.62	1.35	1	5	204
<i>Reduce erosion</i>	3.83	1.42	1	5	214
<i>Reduce costs</i>	2.92	1.30	1	5	178
<i>Control weeds</i>	3.36	1.42	1	5	194
<i>Improve soil quality</i>	3.72	1.40	1	5	210
<i>Improve water quality</i>	3.78	1.36	1	5	199
<i>Increase management burden</i>	3.35	1.36	1	5	186
$y_{nc,i}^*$					
<i>Increase yield</i>	2.08	0.64	1	3	168
<i>Reduce yield variability</i>	2.04	0.68	1	3	145
<i>Retain soil moisture</i>	2.11	0.61	1	3	191
<i>Reduce erosion</i>	2.11	0.54	1	3	201
<i>Reduce costs</i>	2.24	0.71	1	3	168
<i>Control weeds</i>	1.82	0.69	1	3	173
<i>Improve soil quality</i>	2.08	0.55	1	3	193
<i>Improve water quality</i>	2.13	0.56	1	3	184
<i>Increase management burden</i>	1.94	0.74	1	3	167

Table 7. A Priori Hypothesis about Variables for Farmer Perceptions of Using No-Till and Cover Crops

Variable	Hypothesized Sign
<i>age</i>	-
<i>age</i> ²	-
<i>edu</i>	+
<i>income</i>	+
<i>income</i> ²	-
<i>size</i>	+
<i>size</i> ²	-
<i>weeds</i>	+/-
<i>nt</i>	+
<i>cc</i>	+
<i>irrigation</i>	+
<i>yy</i>	+
<i>yn</i>	+

Table 8. Statistical Test of the Differences in Mean Perception and Awareness of Likelihood of Outcome Occurring As a Result of No-Till Adoption Across No-Till Users and Non-Users

Variables	Likelihood of Occurring		Awareness	
	User	Non-User	User	Non-User
Increase yield	3.08*** N=183	1.92*** N=12	0.83*** N=220	0.55*** N=22
Reduce Yield Variability	2.92*** N=158	1.60*** N=10	0.78*** N=202	0.48*** N=21
Retain Soil Moisture	3.90*** N=214	2.62*** N=13	0.94*** N=228	0.59*** N=22
Reduce Erosion	4.10*** N=219	2.80*** N=15	0.96*** N=229	0.65*** N=23
Reduce Costs	3.39*** N=202	2.08*** N=13	0.91*** N=222	0.57*** N=23
Control Weeds	3.21** N=194	2.23** N=13	0.89*** N=217	0.57*** N=23
Improve Soil Quality	3.97*** N=210	2.62*** N=13	0.94*** N=224	0.57*** N=23
Improve Water Quality	4.04*** N=198	2.67*** N=12	0.90*** N=221	0.55*** N=22
Increase Management Burden	3.22 N=185	2.64 N=11	0.86*** N=216	0.50*** N=22

Note: **: mean (user) > mean (non-user) at 5% significance level

***: mean (user) > mean (non-user) at 1% significance level

Table 9. Statistical Test of the Differences in Mean Perception and Awareness of Likelihood of Outcome Occurring As a Result of Cover Crop Adoption Across Cover Crop Users and Non-Users

Variables	Likelihood of Occurring		Awareness	
	User	Non-User	User	Non-User
Increase yield	3.16*** N=73	2.66*** N=117	0.97*** N=75	0.73*** N=161
Reduce Yield Variability	3.15*** N=67	2.31*** N=99	0.96*** N=70	0.65*** N=153
Retain Soil Moisture	3.99*** N=77	3.40*** N=126	0.99*** N=78	0.78*** N=162
Reduce Erosion	4.24*** N=78	3.59*** N=135	0.99*** N=79	0.82*** N=165
Reduce Costs	3.22*** N=67	2.72*** N=110	0.93*** N=72	0.71*** N=156
Control Weeds	3.75*** N=73	3.13*** N=120	0.99*** N=74	0.74*** N=162
Improve Soil Quality	4.15*** N=77	3.46*** N=132	1.00*** N=77	0.80*** N=164
Improve Water Quality	4.16*** N=73	3.55*** N=125	0.99*** N=74	0.78*** N=160
Increase Management Burden	3.47 N=68	3.30 N=116	0.94*** N=72	0.74*** N=157

Note: ***: mean (user) > mean (non-user) at 1% significance level

Table 10. Statistical Test of the Differences in Mean Perception and Awareness of Likelihood of Outcome Occurring As a Result of Cover Crop Adoption Across Cover Crop Abandoners and Never Users

Variables	Likelihood of Occurring		Awareness	
	Abandoner	Never User	Abandoner	Never User
Increase yield	2.71 N=45	2.63 N=72	0.88*** N=51	0.65*** N=110
Reduce Yield Variability	2.65 N=35	2.58 N=64	0.78** N=45	0.59** N=108
Retain Soil Moisture	3.30 N=46	3.45 N=80	0.91*** N=51	0.72*** N=111
Reduce Erosion	3.57 N=47	3.60 N=88	0.90** N=52	0.78** N=113
Increase Profit	3.00 N=38	2.57 N=72	0.83** N=46	0.65** N=110
Control Weeds	3.01 N=45	3.16 N=75	0.87*** N=52	0.68*** N=110
Improve Soil Quality	3.41 N=49	3.49 N=83	0.91*** N=54	0.75*** N=110
Improve Water Quality	3.61 N=46	3.52 N=79	0.90*** N=51	0.72*** N=109
Increase Planting Difficulty	3.40 N=40	3.25 N=76	0.83* N=48	0.70* N=109

Note: *: mean (abandoner) > mean (never user) at 10% significance level

**: mean (abandoner) > mean (never user) at 5% significance level

***: mean (abandoner) > mean (never user) at 1% significance level

Table 11. Statistical Test of the Differences in Mean Perception of Likelihood of Outcome Occurring As a Result of Cover Crop Adoption Across Cover Crop Users and Abandoners

Variables	Likelihood of Occurring	
	User	Abandoner
Increase yield	3.16** N=73	2.71** N=45
Reduce Yield Variability	3.15** N=67	2.65** N=35
Retain Soil Moisture	3.99*** N=77	3.30*** N=46
Reduce Erosion	4.24*** N=78	3.57*** N=47
Reduce Costs	3.22 N=67	3.00 N=38
Control Weeds	3.75*** N=73	3.01*** N=45
Improve Soil Quality	4.16*** N=77	3.41*** N=49
Improve Water Quality	4.16** N=73	3.61** N=46
Increase Management Burden	3.47 N=68	3.40 N=40

Note: **: mean (user) > mean (abandoner) at 5% significance level

***: mean (user) > mean (abandoner) at 1% significance level

Table 12. Statistical Test of the Differences in Mean Perception and Awareness of Likelihood of Outcome Occurring from Adoption of No-Till or Cover Crops for All Respondents

Variables	Likelihood of Occurring		Awareness	
	No-Till	Cover Crops	No-Till	Cover Crops
Increase yield	3.03*	2.91* N=168	0.82	0.8 N=223
Reduce Yield Variability	2.93	2.85 N=145	0.76	0.75 N=207
Retain Soil Moisture	3.88***	3.69*** N=191	0.92***	0.52*** N=231
Reduce Erosion	4.07***	3.90*** N=201	0.94***	0.88*** N=233
Reduce Costs	3.34***	2.95*** N=168	0.89***	0.79*** N=219
Control Weeds	3.15###	3.46### N=173	0.88***	0.82*** N=219
Improve Soil Quality	3.96***	3.81*** N=193	0.91**	0.87** N=229
Improve Water Quality	4.00***	3.80*** N=184	0.88	0.86 N=225
Increase Management Burden	3.22	3.39 N=167	0.84	0.82 N=218

Note: *: mean (no-till) > mean (cover crops) at 10% significance level

**: mean (no-till) > mean (cover crops) at 5% significance level

***: mean (no-till) > mean (cover crops) at 1% significance level

###: mean (no-till) < mean (cover crops) at 1% significance level

Table 13. Statistical Test of the Differences in Mean Perception of Likelihood of Outcome Occurring from Adoption of No-Till and Cover Crops Across No-Till Users and Cover Crop Users

Variables	Likelihood of Occurring	
	No-Till User	Cover Crop User
Increase yield	3.08 N=183	3.16 N=73
Reduce Yield Variability	2.92 N=158	3.15 N=67
Retain Soil Moisture	3.90 N=214	3.99 N=77
Reduce Erosion	4.10 N=219	4.24 N=78
Reduce Costs	3.39 N=202	3.22 N=67
Control Weeds	3.21*** N=194	3.75*** N=73
Improve Soil Quality	3.97 N=210	4.16 N=77
Improve Water Quality	4.04 N=198	4.16 N=73
Increase Management Burden	3.22 N=185	3.47 N=68

Note: ***: mean (no-till user) > mean (cover crop user) at 1% significance level

Table 14. Parameter Estimates for Farmer Perceptions of the Effects of Using No-Till from Ordered Probit Models

Parameters	Farmer Perceptions of the Effects of Using No-Till								
	(1) Increase Yield	(2) Reduce Yield Variability	(3) Retain Soil Moisture	(4) Reduce Erosion	(5) Reduce Costs	(6) Control Weeds	(7) Improve Soil Quality/Health	(8) Improve Water Quality	(9) Increase Management Burden
<i>age</i>	0.0407	-0.0312	0.0454	0.0840*	0.0103	0.0295	0.109**	0.144***	0.0287
<i>age</i> ²	-0.0401	0.0262	-0.048	-0.0857**	-0.0174	-0.0301	-0.106**	-0.131***	-0.029
<i>edu</i>	0.319*	0.455**	0.234	0.202	0.385**	0.317*	0.525***	0.400**	0.285
<i>income</i>	-0.0005	0.0002	0.0015	0.0003	0.0026*	0.0002	0.0009	0.0001	-0.0003
<i>income</i> ²	0.0056	0.0047	0.0055	0.0152	-0.0159	0.0007	0.0088	0.0183	0.014
<i>size</i>	0.0259	0.0021	0.0094	0.015	-0.017	-0.0123	0.036	0.049	0.0121
<i>size</i> ²	-0.3181	0.0021	-0.5466	-0.8716	-0.0305	0.0606	-0.9655	-1.2144**	-0.0006
<i>weeds</i>	-0.0131	0.251	0.0146	0.104	-0.101	-0.348	-0.277	-0.227	0.305
<i>cc</i>	0.0885	0.349	0.391*	0.298	0.0301	0.198	0.140	0.161	-0.0637
<i>irrigation</i>	0.249	0.386	0.572*	1.087***	0.697**	0.604**	0.759**	0.815**	0.421
<i>yy</i>	0.0744	0.213	0.171	0.214	0.573	0.0927	-0.005	0.292	-0.619
<i>yn</i>	-0.224	-0.154	-0.195	-0.311	-0.0487	-0.127	-0.433*	-0.199	-0.0563
<i>cut1</i>	0.474	-0.907	-0.198	0.662	-0.805	-0.420	0.925	2.286*	0.0994
<i>cut2</i>	0.779	-0.460	0.343	1.059	-0.330	0.0752	1.646	2.883**	0.528
<i>cut3</i>	1.587	0.274	0.904	1.624	0.390	0.978	2.332*	3.598***	1.246
<i>cut4</i>	2.036	0.773	1.607	2.126	0.989	1.568	2.973**	4.106***	1.726
<i>N</i>	140	123	161	164	152	149	157	151	138

Note: * = significant at a 10% level, ** = significant at a 5% level, *** = significant at a 1% level.

Table 15. Parameter Estimates for Farmer Perceptions of the Effects of Using Cover Crops from Ordered Probit Models

Parameters	Farmer Perceptions of the Effects of Using Cover Crops								
	(1) Increase Yield	(2) Reduce Yield Variability	(3) Retain Soil Moisture	(4) Reduce Erosion	(5) Reduce Costs	(6) Control Weeds	(7) Improve Soil Quality/Health	(8) Improve Water Quality	(9) Increase Management Burden
<i>age</i>	0.0475	0.00439	0.0985*	0.117**	0.0299	0.0542	0.0366	0.0894	0.0072
<i>age</i> ²	-0.0474	0.0002	-0.107**	-0.120***	-0.0296	-0.0609	-0.0593	-0.0972**	-0.0258
<i>edu</i>	-0.089	0.109	-0.106	-0.0578	-0.116	0.111	-0.136	-0.0268	0.121
<i>income</i>	-0.0006	-0.0003	-0.0008	-0.0039	0.0001	-0.0008	-0.0021	-0.0068**	0.0001
<i>income</i> ²	0.0129	0.0095	0.0152	0.116	0.0088	0.0087	0.0635	0.1580**	0.0064
<i>size</i>	-0.0069	0.0076	0.0404	0.0518*	-0.0392	0.0028	0.0237	0.0352	0.0027
<i>size</i> ²	-0.1126	-0.3876	-0.8593	-1.0514*	0.408	-0.3933	-0.6281	-0.8118	0.1796
<i>weeds</i>	-0.149	0.0837	0.0656	0.181	-0.360	-0.171	-0.221	-0.390	0.462*
<i>nt</i>	0.677*	0.596	1.331***	1.213***	0.403	0.761**	1.001***	0.863**	1.183***
<i>irrigation</i>	0.578*	0.419	0.318	0.348	0.319	0.467	0.290	0.448	0.277
<i>cyy</i>	0.765***	0.563**	0.303	0.592**	0.611**	0.562**	0.739**	1.022***	0.0025
<i>cyn</i>	-0.142	-0.343	-0.174	-0.182	0.0372	0.187	0.166	0.103	-0.480*
<i>cut1</i>	0.929	0.321	1.918	2.538	-0.0191	0.592	-0.553	0.792	0.0102
<i>cut2</i>	1.307	0.701	2.366	2.945*	0.447	1.111	-0.109	1.261	0.258
<i>cut3</i>	2.349	1.750	3.098*	3.355**	1.188	1.693	0.431	1.810	1.105
<i>cut4</i>	3.052*	2.376	3.800**	4.049**	1.943	2.403	1.053	2.481	1.821
<i>N</i>	129	115	141	146	121	130	140	133	129

Note: * = significant at a 10% level, ** = significant at a 5% level, *** = significant at a 1% level.

Table 16. Parameter Estimates for Farmer Group Perceptions of the Common Effects of Using No-till and Cover Crops from Ordered Probit Models

Parameters	Farmer Group Perceptions of the Effects of Using the Practices								
	(1) Increase Yield	(2) Reduce Yield Variability	(3) Retain Soil Moisture	(4) Reduce Erosion	(5) Reduce Costs	(6) Control Weeds	(7) Improve Soil Quality/Health	(8) Improve Water Quality	(9) Increase Management Burden
<i>age</i>	0.0389	-0.0837	-0.0415	0.0287	0.0149	-0.0291	0.0556	0.0238	0.0341
<i>age</i> ²	-0.0349	0.063	0.0419	-0.0297	-0.0101	0.0299	-0.0247	-0.00245	-0.0102
<i>edu</i>	0.593***	0.657***	0.318	0.137	0.401*	0.262	0.698***	0.496**	0.237
<i>income</i>	0.0019	-0.0001	0.0011	0.0002	0.0015	-0.0006	0.0015	0.0023	-0.0027
<i>income</i> ²	-0.0195	0.0068	-0.0047	-0.006	-0.0112	0.0006	0.0193	-0.0271	0.0196
<i>size</i>	-0.0399	-0.0817*	-0.0533	-0.039	-0.0229	-0.0696*	-0.0033	0.0012	0.0041
<i>size</i> ²	0.8183	1.8369*	0.8845	0.441	0.4932	2.1544**	0.1442	-0.0111	-0.4132
<i>weeds</i>	0.587**	0.527*	0.433	0.431	0.462	-0.0263	0.425	0.647**	0.241
<i>irrigation</i>	-0.315	-0.0404	-0.228	0.0166	0.324	-0.574*	0.103	0.0821	0.00284
<i>yy</i>	-0.0273	0.721	0.0969	0.540	0.453	-0.587	0.707	0.432	-0.321
<i>yn</i>	0.493	0.392	-0.247	-0.0979	0.395	0.126	0.0882	0.195	-0.251
<i>cyy</i>	-0.511	-0.348	0.272	0.104	-0.482	0.395	-0.761**	-0.651**	0.173
<i>cyn</i>	0.203	0.758**	0.457	0.261	0.114	0.0384	-0.454	-0.190	0.118
<i>cut1</i>	0.477	-2.982	-1.684	-0.414	0.115	-1.186	1.593	0.852	1.17
<i>cut2</i>	2.392	-1.199	0.161	1.782	1.486	0.312	3.936**	2.940*	2.464
<i>N</i>	117	104	134	142	116	122	132	129	120

Note: * = significant at a 10% level, ** = significant at a 5% level, *** = significant at a 1% level.

Q10. How likely is each of the following to occur from using **no-till** on your farm? (Check one box for each result)

← Less Likely---Chance of Occurring---More Likely →

	0-25%	25-49%	50/50%	51-75%	75-100%	No Idea
Increase yield	☐	☐	☐	☐	☐	☐
Reduce yield variability	☐	☐	☐	☐	☐	☐
Retain soil moisture	☐	☐	☐	☐	☐	☐
Reduce erosion	☐	☐	☐	☐	☐	☐
Reduce costs	☐	☐	☐	☐	☐	☐
Control weeds	☐	☐	☐	☐	☐	☐
Improve soil quality/health	☐	☐	☐	☐	☐	☐
Improve water quality	☐	☐	☐	☐	☐	☐
Increase management burden	☐	☐	☐	☐	☐	☐

Figure 2. Question Used to Estimate Producer Perceptions of the Effects of Using No-Till

Q17. How likely is each of the following to occur from using **cover crops** on your farm? (Check one box for each result)

← Less Likely---Chance of Occurring---More Likely →

	0-25%	25-49%	50/50%	51-75%	75-100%	No Idea
Increase yield	☐	☐	☐	☐	☐	☐
Reduce yield variability	☐	☐	☐	☐	☐	☐
Retain soil moisture	☐	☐	☐	☐	☐	☐
Reduce erosion	☐	☐	☐	☐	☐	☐
Increase profit	☐	☐	☐	☐	☐	☐
Control weeds	☐	☐	☐	☐	☐	☐
Improve soil quality/health	☐	☐	☐	☐	☐	☐
Improve water quality	☐	☐	☐	☐	☐	☐
Increase planting difficulty	☐	☐	☐	☐	☐	☐

Figure 3. Question Used to Estimate Producer Perceptions of the Effects of Using Cover Crops

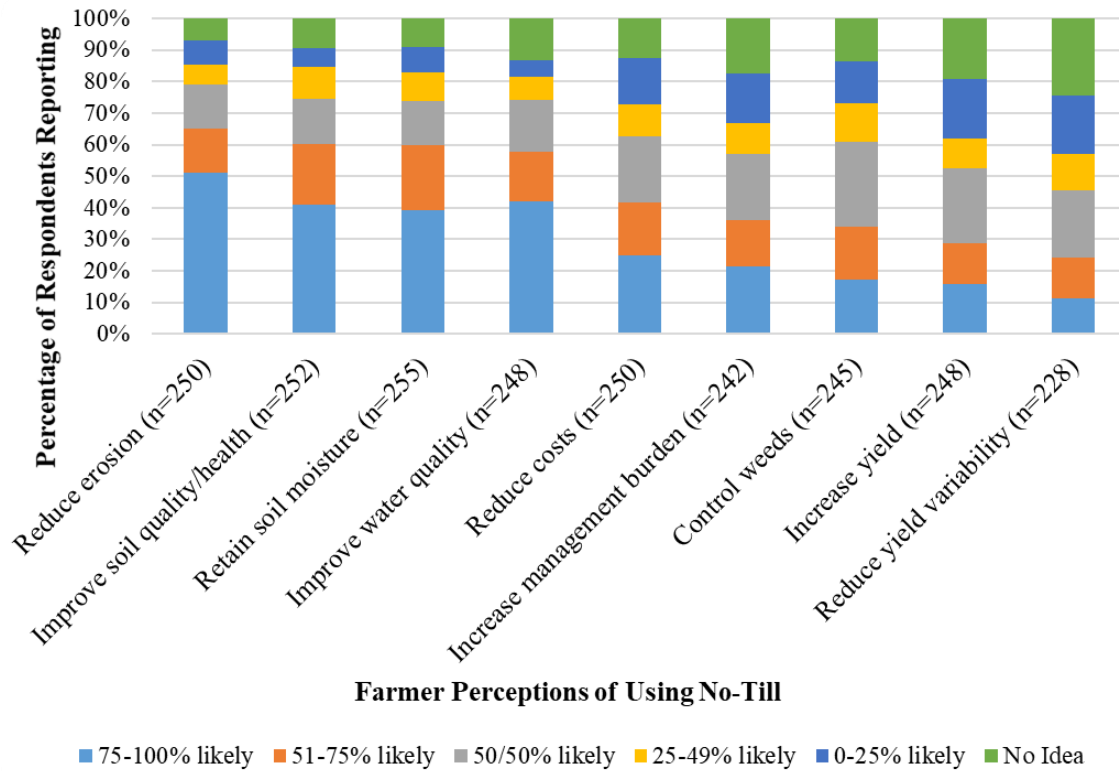


Figure 4. Distribution of Respondent Perceptions Regarding the Likelihood of Outcomes to Occur from Using No-Till

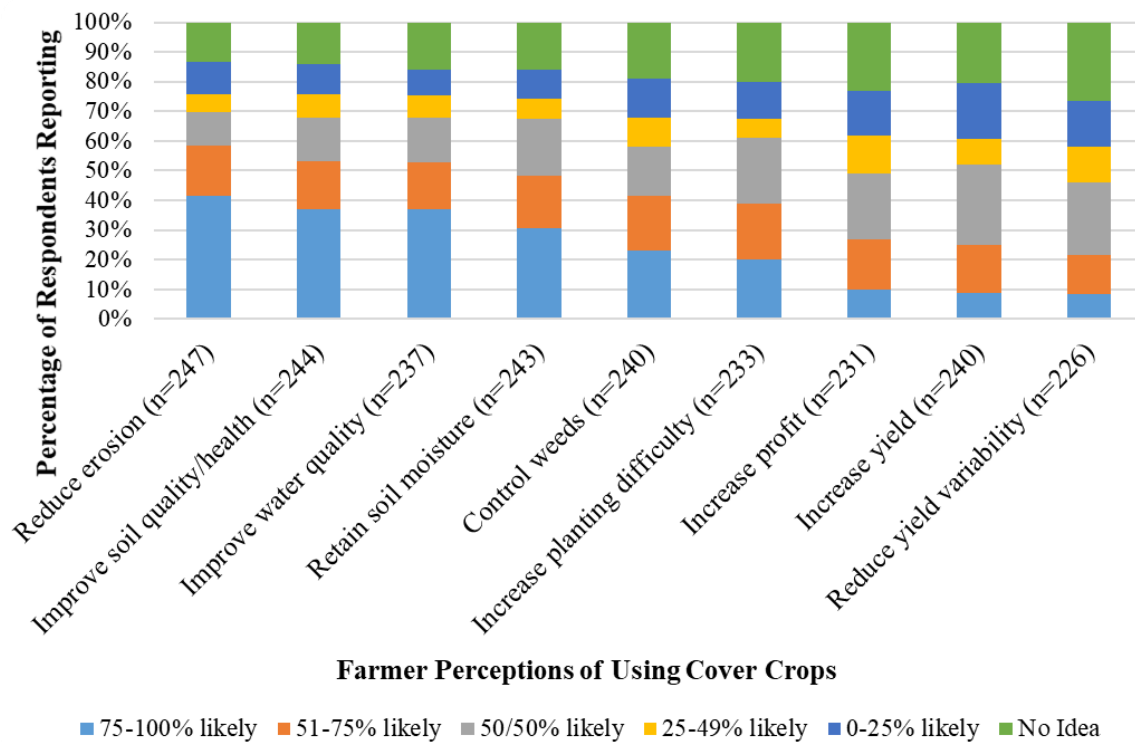


Figure 5. Distribution of Respondent Perceptions Regarding the Likelihood of Outcomes to Occur from Using Cover Crops

CHAPTER III
THE USE OF COVER CROPS IN MIDDLE AND WEST
TENNESSEE

Methods

Whether or not the respondent planted cover crops in 2016 (Figure 6 in Appendix D) is used as a dependent variable. Previous studies suggest that demographic and farm characteristics influence the adoption of cover crops. Education level (Burnett et al. 2018; Mishra et al. 2018), willingness to take risks (Burnett et al. 2018; Carlisle 2016), farmed acres (Prokopy et al. 2008), use of irrigation (Bergtold et al. 2012; Mishra et al. 2018), planting row crops (Bergtold et al. 2012; Mishra et al. 2018), and engaging in another conservation practice (Carlisle 2016) have been shown to be positively correlated with the use of cover crops. However, age (Burnett et al. 2018; Hussain et al. 2010; Carlisle 2016) and farm income (Burnett et al. 2018) were found to be negatively correlated with cover crop adoption. Therefore, producers' age (*age* and *age*²), education level (*edu*), farmed acres (*size*), farm income (*income*), use of irrigation (*irrigation*), and planted crops (*corn*, *cotton*, *soybean*, *wheat*, *other*) are included in the analysis of the use of cover crops.

Rosch (2017) found that risk attitudes were related to farmers' participation in Federal Crop Insurance programs, and thus whether a farmer had crop insurance in 2016 (*cropins*) is used as an independent variable to represent a farmer's willingness to take risks. In addition, although land tenure (*tenure*) did not appear to impact cover crop adoption in previous studies (Carlisle 2016; Bergtold et al. 2012), this factor, as well as whether the producer had identified herbicide-resistant weeds (*weeds*), are also used as independent variables.

Respondent responses to the question about the use of cover crops were used to create two separate dichotomous variables: (i) whether a farmer was a cover crop user ($y^*_{user,i} = 1$ if a farmer used cover crops in 2016, otherwise = 0) and (ii) whether a farmer was a cover crop never user ($y^*_{never,i} = 1$ if a farmer has never used cover crops otherwise = 0). Bivariate probit models are used to analyze whether the use of cover crops and the use of no-till are related, and there are two bivariate probit models for users and never users. If a correlation coefficient (ρ) between the residuals of the two probits is significantly different from zero, then these two probits should be estimated simultaneously, and a bivariate probit model is necessary. However, if a correlation coefficient (ρ) between the residuals of the two probits is not significantly different from zero, two separate probit models can be used to estimate the parameters.

The use of cover crops equation is specified as:

$$(14) y^*_{user,i} = \omega_0 + \omega_1 age_i + \omega_2 age_i^2 + \omega_3 edu_i + \omega_4 income_i + \omega_5 cropins_i + \omega_6 size_i + \omega_7 tenure_i + \omega_8 weeds_i + \omega_9 irrigation_i + \omega_{10} corn_i + \omega_{11} cotton_i + \omega_{12} soybean_i + \omega_{13} wheat_i + \omega_{14} other_i + \varepsilon_{user,i},$$

$$(15) y^*_{never,i} = \kappa_0 + \kappa_1 age_i + \kappa_2 age_i^2 + \kappa_3 edu_i + \kappa_4 income_i + \kappa_5 cropins_i + \kappa_6 size_i + \kappa_7 tenure_i + \kappa_8 weeds_i + \kappa_9 irrigation_i + \kappa_{10} corn_i + \kappa_{11} cotton_i + \kappa_{12} soybean_i + \kappa_{13} wheat_i + \kappa_{14} other_i + \varepsilon_{non,i},$$

where $y^*_{user,i}$ and $y^*_{never,i}$ are the respondents' use of cover crops in 2016, including whether they were users in 2016 and whether they were never users, respectively. The definitions of the dependent and explanatory variables are provided in Table 17 in Appendix D. Summary statistics for the variables are provided in Table 18 in Appendix D.

In addition, in order to analyze the effects of factors on cover crop abandoners, a multinomial probit model (MNP) was also used in this study to estimate the parameters for cover crop users and abandoners when never users were considered as the base outcome. Thus, the model is specified as:

$$(16) y_{ij}^* = B_j X_i + \varepsilon_{ij},$$

where y_{ij}^* is coded as one, two, and three for the respondent was a cover crop user, abandoner, and never user, respectively; X_i is a vector of explanatory variables that were the same as those in probit models. The definitions and summary statistics for the variables are provided in Tables 17 and 18 in Appendix D, respectively.

A Priori Hypothesis about Variables

Predicted signs for the estimated coefficients for all of the variables for cover crop users are provided in Table 19 in Appendix D. The variable *age* is predicted to have a negative sign since previous studies indicated that younger producers can benefit from long-term conservation practices and have a more positive attitude toward conservation practices (Burnett et al. 2018; Hussain et al. 2010; Carlisle 2016). The variable *edu* is expected to have a positive sign since studies found that producers with a college degree were more likely to adopt conservation practices (Burnett et al. 2018; Mishra et al. 2018). Based on Burnett et al.'s (2018) finding, farmers with less farm income were more willing to adopt cover crops, so the coefficient of *income* is hypothesized to have a negative sign. The variable *cropins* is predicted to have a positive sign since Rosch (2017) indicated that risk-seeking farmers were more likely to have crop insurance, and if

farmers were more willing to take risks, they were more likely to use cover crops (Burnett 2018; Carlisle 2016).

Producers having larger farms were more likely to plant cover crops, as they may get benefits from economies of scale in fixed costs (Prokopy et al. 2008). Thus, the coefficient of the variable *size* is expected to be positive. Previous studies concluded that producers growing row crops were more likely to use cover crops or sustainable agriculture practices (Bergtold et al. 2012; Mishra et al. 2018). Therefore, the variables *corn*, *cotton*, *soybean*, *wheat*, and *other* are expected to have a positive sign. No hypotheses are preferred for the variables *weeds* and *tenure* because the correlation between cover crop adoption and whether the producer had identified herbicide-resistant weeds (Campbell 2018) or land tenure (Carlisle 2016; Bergtold et al. 2012) is uncertain. Bergtold et al. (2012) and Mishra et al. (2018) found that producers who use irrigation are more likely to adopt cover crops or other conservation practices, so the coefficient for *irrigation* is hypothesized to be positive.

Since cover crop never users are respondents who have never used cover crops, the predicted signs for the estimated coefficients for all of the variables for cover crop never users are expected to be opposite to those for cover crop users (Table 19 in Appendix D). However, the effects of all variables on the use of cover crop in multinomial probit model for cover crop abandoners are uncertain. Thus, no hypotheses are preferred for all of the variables for abandoners in the model.

Results

The results of bivariate probit models for the use of cover crops and the use of no-till are provided in Table 20 in Appendix D. The first two columns are the parameter estimates for whether farmers were cover crop users and whether farmers were no-till users. The correlation coefficient (ρ) between the residuals of the two probits was -0.0651, but it was not statistically significantly different from zero at a 10% significance level (Table 20 in Appendix D), indicating that the correlation between cover crop users and no-till users was weak. Thus, it is not necessary to use a bivariate probit model, and separate probit models are going to be used to estimate the parameters.

The second two columns show the parameter estimates for whether farmers were cover crop never users and no-till users. Although the correlation coefficient (ρ) between the residuals of these two probits was -0.0003, it was not statistically significant at a 10% level (Table 20 in Appendix D). Therefore, the bivariate probit model is not necessary and separate probit models are going to be used to estimate the parameters.

The results of the separate probit models for the use of cover crops are provided in Table 21 in Appendix D. In the first equation, the dependent variable is whether a farmer used cover crops in 2016 (“user”). The coefficients for the variables *cropins* and *cotton* were significantly and positively correlated with cover crop use at a 5% significance level. This result indicates that farmers with crop insurance and who planted cotton were more likely to use cover crops in 2016. In addition, in terms of significant marginal effects, the marginal effects for *cropins* and *cotton* were 0.172 and 0.215, respectively. Therefore, producers who had crop insurance were 17.2% more likely to use

cover crops in 2016 than those who did not have crop insurance, and producers who planted cotton were 21.5% more likely to use cover crops in 2016 than others were.

The dependent variable in the second equation is whether a farmer had never used cover crops (“never user”). However, according to the Table 21 in Appendix D, no variables were significant at a 10% level. These results indicate that none of the variables had a significant impact on whether these farmers were cover crop never users.

Therefore, this is not enough information to infer the relationship between farmers who were never users and the factors of their demographics, farm characteristics, and experiences.

Table 22 in Appendix D shows the results of the parameter estimates from the multinomial probit model (MNP). When never users were used as the base outcome, the coefficients for the variables *cropins* and *cotton* were statistically significant and positive for cover crop users in 2016, which was the same as the results of the single probit model for cover crop users. Thus, in comparison to never users, producers who had crop insurance and planted cotton were correlated with higher likelihoods of being cover crop users in 2016. However, in terms of cover crop abandoners, none of the variables was statistically significant at a 10% level. Therefore, in comparison to never users, none of the variables had a significant impact on whether a producer was a cover crop abandoner.

Conclusions

Planting cover crops can generate both public benefits and private benefits, such as preventing soil erosion, protecting water quality, increasing yields, and reducing the need for herbicides (Clark 2008). Presumably, these benefits could motivate producers to adopt cover crops. While the acres of cropland planted with cover crops increased from 2012 to 2016, the number of planted acres is still a small fraction of the total cropland in the U.S. (SARE and CTIC 2017). A better understanding of the factors affecting producers' use of cover crops could help in the evaluation and design of policies and programs to promote their adoption. Thus, this study used data from a 2017 survey of Middle and West Tennessee row crop producers to analyze factors influencing producers' use of cover crops.

Referring to previous studies, farmer demographics, experience in farming, and farm characteristics were used as explanatory variables. The results from bivariate probit models showed that there was not a statistically significant correlation between the use of no-till and the use of cover crops, and thus single probit models were used to estimate the parameters for the use of cover crops.

In terms of the single probit model, none of the variables had a significant impact on the use of cover crops for never users. In terms of the multinomial probit model, compared to never users, no variables significantly affected the use of cover crops for abandoners. Thus, we do not have sufficient information to indicate that farmer demographics, experience, and farm characteristics will influence a farmer to be a cover crop never user or abandoner. However, having crop insurance and planting cotton were

positively correlated with the use of cover crops in 2016 in both single probit and multinomial probit models. Therefore, based on this result, the recommendation for further research is to explore the relationships between the use of cover crops and crop insurance and cotton planting.

Appendix D Tables and Figures

Table 17. Definition of Dependent Variables and Explanatory Variables

Variable	Description
<i>Dependent Variables</i>	
<i>Single Probit Models</i>	
$y_{user,i}^*$	= 1 if respondent used cover crops in 2016; otherwise = 0
$y_{never,i}^*$	= 1 if respondent has never used cover crops; otherwise = 0
<i>Multinomial Probit Model</i>	
y_{ij}^*	= 1 if respondent used cover crops in 2016; = 2 if respondent has previously used cover crops but did not in 2016; = 3 if respondent has never used cover crops
<i>Independent Variables</i>	
<i>age</i>	Age of farmer (years)
<i>age</i> ²	Square of farmer age (100 years)
<i>edu</i>	= 1 if respondent has a college degree; otherwise = 0
<i>income</i> ⁴	Total farm income in 2016 (\$1,000)
<i>cropins</i>	= 1 if respondent had crop insurance in 2016; otherwise = 0
<i>size</i>	Acres farmed in 2016 (100 acres)
<i>tenure</i>	Owned farmed acres divided by size
<i>weeds</i>	= 1 if respondent has identified herbicide-resistant weeds on farm; otherwise = 0
<i>irrigation</i>	= 1 if respondent irrigated in 2016; otherwise = 0
<i>corn</i>	= 1 if respondent planted corn in 2016; otherwise = 0
<i>cotton</i>	= 1 if respondent planted cotton in 2016; otherwise = 0
<i>soybean</i>	= 1 if respondent planted soybean in 2016; otherwise = 0
<i>wheat</i>	= 1 if respondent planted wheat in 2016; otherwise = 0
<i>other</i>	= 1 if respondent planted other crops in 2016; otherwise = 0

⁴ Total farm income is the product of percent of total household income from farming and midpoints of categorical total household income response options.

Table 18. Summary Statistics of Dependent Variables and Explanatory Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	N
<i>Dependent Variables</i>					
<i>Single Probit Models</i>					
$y^*_{user,i}$	0.29	0.46	0	1	302
$y^*_{never,i}$	0.49	0.50	0	1	302
<i>Multinomial Probit Model</i>					
y^*_{ij}	2.20	0.86	1	3	302
<i>Independent Variables</i>					
<i>age</i>	63.51	14.15	21	98	318
<i>age</i> ²	42.34	17.25	4.41	96.04	318
<i>edu</i>	0.41	0.49	0	1	329
<i>income</i>	95.77	191.73	0	1100	296
<i>cropins</i>	0.58	0.49	0	1	321
<i>size</i>	5.71	11.64	0	100	346
<i>tenure</i>	61.28	40.52	0	100	331
<i>weeds</i>	0.69	0.46	0	1	253
<i>irrigation</i>	0.15	0.36	0	1	275
<i>corn</i>	0.47	0.50	0	1	346
<i>cotton</i>	0.15	0.36	0	1	346
<i>soybean</i>	0.72	0.45	0	1	346
<i>wheat</i>	0.29	0.47	0	1	346
<i>other</i>	0.07	0.26	0	1	346

Table 19. A Prior Hypothesis about Variables for Cover Crop Users and Non-Users

Variable	Hypothesized Sign	
	User	Never User
<i>age</i>	-	+
<i>age</i> ²	+	-
<i>edu</i>	+	-
<i>income</i>	-	+
<i>cropins</i>	+	-
<i>size</i>	+	-
<i>tenure</i>	+/-	+/-
<i>weeds</i>	+/-	+/-
<i>irrigation</i>	+	-
<i>corn</i>	+	-
<i>cotton</i>	+	-
<i>soybean</i>	+	-
<i>wheat</i>	+	-
<i>other</i>	+	-

Table 20. Parameter Estimates for the Use of Cover Crops and No-Till from Bivariate Probit Models

	(1)		(2)	
Parameters	Cover Crops User	No-Till User	Cover Crops Never User	No-Till User
Intercept	-2.314	-0.664	0.334	-0.744
<i>age</i>	0.0579	0.0278	0.00223	0.0303
<i>age</i> ²	-0.0728	-0.0308	-0.0021	-0.0325
<i>edu</i>	0.0823	0.165	-0.0663	0.172
<i>income</i>	-0.0001	0.0016	-0.0005	0.0016
<i>cropins</i>	0.544**	0.0397	-0.282	0.0321
<i>size</i>	0.0207	0.0244	-0.0204	0.0232
<i>tenure</i>	0.225	0.481	0.0004	0.0047
<i>weeds</i>	-0.355	-0.045	-0.0267	-0.0449
<i>irrigation</i>	-0.082	4.460	0.178	4.326
<i>corn</i>	0.293	0.942**	-0.0276	0.937**
<i>cotton</i>	0.659**	0.316	-0.236	0.296
<i>soybean</i>	0.378	0.518	-0.0425	0.519
<i>wheat</i>	0.0847	0.667	0.105	0.663
<i>other</i>	0.0349	5.000	-0.0772	4.737
<i>rho</i>	-0.0651		-0.0003	
<i>N</i>	184		184	

Note: ** = significant at a 5% level.

Table 21. Parameter Estimates and Significant Marginal Effects for the Use of Cover Crops from Probit Models

Parameters	The Use of Cover Crops		
	User		Never User
	Parameter Estimates	Marginal Effects	Parameter Estimates
Intercept	-2.471	-	0.174
<i>age</i>	0.0591	-	0.0118
<i>age</i> ²	-0.0730	-	-0.0125
<i>edu</i>	0.0968	-	-0.0698
<i>income</i>	-0.0001	-	-0.0005
<i>cropins</i>	0.545**	0.172**	-0.267
<i>size</i>	0.0206	-	-0.0207
<i>tenure</i>	0.2026	-	0.0008
<i>weeds</i>	-0.310	-	-0.0787
<i>irrigation</i>	-0.0743	-	0.157
<i>corn</i>	0.303	-	-0.0155
<i>cotton</i>	0.679**	0.215**	-0.240
<i>soybean</i>	0.414	-	-0.025
<i>wheat</i>	0.0787	-	0.111
<i>other</i>	0.0728	-	-0.130
<i>N</i>	190		190

Note: ** = significant at a 5% level.

Table 22. Parameter Estimates for the Use of Cover Crops from Multinomial Probit Models

Parameter	The Use of Cover Crops		
	Current User	Abandoner	Never User (Base Outcome)
Intercept	-2.897	-1.027	-
<i>age</i>	0.0652	-0.0248	-
<i>age2</i>	-0.0769	0.0506	-
<i>edu</i>	0.141	0.0285	-
<i>income</i>	0.0004	0.0013	-
<i>size</i>	0.0296	0.0036	-
<i>tenure</i>	0.0014	-0.0046	-
<i>cropins</i>	0.733*	0.0422	-
<i>weeds</i>	-0.282	0.480	-
<i>irrigation</i>	-0.184	-0.304	-
<i>corn</i>	0.307	-0.306	-
<i>cotton</i>	0.816*	-0.373	-
<i>soybean</i>	0.476	-0.259	-
<i>wheat</i>	0.0221	-0.237	-
<i>other</i>	0.172	0.282	-
<i>N</i>		190	

Note: * = significant at a 10% level.

Q12. Did you plant cover crops in 2016?

- ☐ Yes (*GO TO Question Q13*)
- ☐ No, but I have previously used them (*GO TO Question Q14*)
- ☐ No, I have *never* used cover crops (*GO TO Question Q16*)

Figure 6. Question Used to Estimate Farmers' Adoption of Cover Crops

CHAPTER IV

Discussion

Soil erosion causes the loss of soil nutrients, which would lead to a reduction in potential crop yield and productivity. While fertilization can provide sufficient nutrients for crop growth, it is limited to recover production by increasing the input of fertilizer in fragile soils (Lal and Moldenhauer 1987; Al-Kaisi et al. 2002). Therefore, if farmers would like to maintain or increase crop productivity, it is important for them to adopt conservation practices to reduce erosion and improve soil health.

The costs of implementing agricultural best management practices (BMPs) include costs to farmers, government, and society (Shortle et al. 2013). The cost to farmers, or the private costs, include the out-of-pocket costs of adopting and maintaining the BMPs and any foregone revenue associated with the adoption of the BMP (as might occur when crop or pasture land is reduced), net of any subsidies received in exchange for implementing the BMP. Government costs include the financial assistance provided to agricultural producers to promote BMP adoption as well as expenditures on technical assistance to support the use of BMPs. Society's costs include increased prices of agricultural products associated with increased production costs and/or decreases in production levels, as well as net welfare loss resulting from public subsidies and/or tax payments.

Farmer decisions as to whether to install BMPs or not can be expected to depend on private benefits and costs. For example, the use of no-till can help save time, as producers just need to till the field once, which also saves labor and fuel costs (Creech

2017). In addition, using no-till can reduce soil erosion and moisture loss providing producers with private benefits in the form of healthier soil and society with public benefits in the form of reduced water quality degradation. Improving soil health can reduce yield variability and improve drought tolerance (Regoli 2019). However, it takes time to see the benefits of no-till. Additionally, since no-till cannot control weeds through tillage, no-till users may be more dependent on herbicides, thereby increasing producer expenditures on herbicides. The initial cost of no-till equipment is also a major barrier for producers to adopt the practice (Regoli 2019).

Cover crops can also improve soil health and water infiltration, control soil erosion, and increase crop yield, although it may take farmers a few years to see these benefits (SARE 2015). Compared to no-till, cover crops are more likely to control herbicide-resistant weeds (SARE and CTIC 2016). The main cost of establishing cover crops is seed cost (Bergtold et al. 2017). A survey conducted by SARE and CTIC (2013) showed that 33% of respondents indicated that seed cost is one of the biggest barriers to cover crop use. Expenditures on machinery purchases and fertilizer application may also increase the costs of using cover crops (Bergtold et al. 2019). In addition, labor and time required to manage the practice and seeding the right species on cropland are barriers that producers may encounter when planting cover crops (Wang 2018).

Previous studies suggest the costs of cover crops are an important barrier to farmer adoption of cover crops (Bergtold et al. 2017; SARE and CTIC 2013). Thus, combined with previous chapters, increasing the adoption rate of cover crops may require

some combination of enhancing producer understanding of the benefits of using cover crops and programs that reduce the costs of cover crops.

The 1985 Farm Bill includes several important agricultural conservation provisions aimed at conserving soil and water resources. Highly Erodible Land Conservation (HELC) and Wetland Conservation (WC) provisions are included in the Farm Bill and collectively referred to as conservation compliance (Stubbs 2012). The conservation compliance provisions are designed to reduce soil loss caused by erosion on erodible land, reduce sedimentation and improve water quality, and protect wetlands to provide their multiple benefits (USDA NRCS 2014). Based on the provisions, producers who participate in most of the programs administered by the Farm Service Agency (FSA) and the Natural Resources Protection Authority (NRCS) are required to use a conservation system on highly erodible land and prohibited from planting an agricultural commodity on a converted wetland (USDA FSA 2014). The result of these provisions, according to Denton and Tyler's (2002) study, was a considerable increase in the adoption of no-till in West Tennessee in the 1990s, as most cropland in this region is highly erodible and the cost of using no-till is relatively lower than other conservation methods.

The 2014 Farm Bill also addresses conservation compliance and requires producers who receive USDA benefits administered by FSA and NRCS to comply with the HELC and WC provisions. Furthermore, it re-links crop insurance premium subsidy paid by the Federal Crop Insurance Corporation (FCIC) to conservation compliance, meaning that producers must comply with the provisions if they would like to be eligible

for premium subsidies (USDA NRCS 2014). The survey population for this study was comprised of row crop producers who received FSA payments. Thus, they would generally have been required to comply with the conservation compliance provisions since many would have been farming on highly erodible land. This requirement could be the reason why the adoption rates of conservation practices for the survey respondents were much higher than those reported in the 2017 Census of Agriculture.

Conclusion

This study utilized data from a 2017 survey of Middle and West Tennessee row crop producers to analyze producers' opinions on the use of no-till and cover crops, and the use of cover crops in Middle and West Tennessee. The results from the survey reveal that the respondents believed the most likely effect of using no-till and cover crops was reducing soil erosion, followed by improving soil quality/health. However, they were less likely to believe that the use of no-till would reduce yield variability, increase yield, or control weeds. They also did not believe that using cover crops was likely to increase profit, increase yield, or reduce yield variability.

No-till users were more confident of and more likely to have an opinion on the likelihood of the effects of using no-till than non-users. Similarly, cover crop users were more likely to believe and have an opinion on the likelihood of the possible outcomes occurring from using cover crops than non-users. Cover crop abandoners had higher levels of awareness of all of the effects of using cover crops than never users, while they did not have a significant difference in mean perceptions of the likelihood of each result occurring from cover crops. On the other hand, cover crop users had more positive

perceptions of the outcomes occurring from the use of cover crops than cover crop abandoners. In addition, on average, cover crop users were more confident that cover crop use would control weeds than no-till users were that no-till use would control weeds.

For farmer perceptions of the effects of using no-till, respondents with more education and irrigation experience were more likely to have positive perceptions of the effects of using no-till. However, age was positively correlated with the likelihood of some outcomes occurring from no-till. For farmer perceptions of the effects of using cover crops, respondents who used no-till or both knew about and had received a cost-share payment for cover crops were more likely to have positive attitudes of the benefits of the use of cover crops. For farmer perceptions of common effects of using no-till and cover crops, respondents who have a college degree were more likely to believe the use of no-till has equal or higher likelihood to cause the outcomes than the use of cover crops. However, respondents who both knew about and had received a cost-share payment for cover crops were less likely to believe that using no-till is more likely to cause the outcomes than cover crops. These findings can enable a better understanding of farmers' opinions of these practices and the factors that influence their perceptions, and improve the design of programs to promote their adoption.

In the chapter on the analysis of the use of cover crops in Middle and West Tennessee, for cover crop never users and abandoners, the results show that no variables significantly affected their use of cover crops. Therefore, this is not sufficient information to infer the relationship between cover crop never users and abandoners and the factors of their demographics, farm characteristics, and experience. However, producers who had

crop insurance or planted cotton were positively correlated with the use of cover crops in 2016. Therefore, based on this result, the recommendation for further research is to explore the relationship between cover crops and cotton and the relationship between cover crops and crop insurance.

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