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Tennessee Row Crop Producer Survey on Willingness to Adopt Best Management Practices

Kelsey Michelle Campbell
University of Tennessee

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I am submitting herewith a thesis written by Kelsey Michelle Campbell entitled "Tennessee Row Crop Producer Survey on Willingness to Adopt Best Management Practices." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural and Resource Economics.

Christopher N. Boyer, Major Professor

We have read this thesis and recommend its acceptance:

Christopher D. Clark, Dayton M. Lambert, S. Aaron Smith

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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ABSTRACT

This thesis presents two separate studies focusing on best management practice (BMP) adoption by row crop producers in Middle and West Tennessee. The objective of the first study is to summarize results the survey. Survey topics included producer perceptions regarding the benefits and costs from using no-tillage planting (no-till), cover crops, and irrigation water management (IWM); respondent responsiveness to BMP cost-share payments; and producer demographic information such as household income and age. The majority of survey respondents (87%) were already planting using no-till, but only 28% knew they could receive a cost-share payment for adopting no-till. Adoption of cover crops was about 29%, and no respondent indicated they have adopted IWM.

Roughly half of producers were aware of United States Department of Agriculture cost-share programs for cover crop adoption, and no producers knew cost-share payments for adopting IWM are available. Producers were responsive to increases in cost-share payments encouraging cover crop adoption; however, producer adoption of no-till and IWM was not responsive to increases in cost-share payments. Data gathered from this survey indicates Tennessee producers' adoption and barriers to adoption of these BMPs, which could assist in designing effective conservation policies.

The objective of the second study is to determine the effect of producer risk preference and other factors such as cost-share payments on willingness to adopt cover crops and no-till using a risk preference elicitation method. The same survey data was used. The results show that producers are responsive to cost-share payments for cover crop adoption, but the likelihood a producer would adopt no-till did not increase with higher cost-share payments. More risk averse producers were less likely to adopt cover crops and no-till, as were those who did not believe the survey would influence future farm programs. Younger, college educated producers were more risk tolerant than older producers without a 4-year degree. The results provide a better understanding of producer risk preferences and will guide future studies in measuring and assessing risk preferences of agricultural producers.

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INTRODUCTION

Increases in water usage and climate uncertainties have led to growing concern regarding the availability and preservation of adequate, clean, and fresh water sources for agricultural production. Irrigated cropland is anticipated to expand globally to meet increasing demand for food, fiber, and energy production (Rosegrant, Ringler, and Zhu, 2009; Schaible and Aillery, 2012). Furthermore, anticipated climate viability such as more frequent prolonged droughts could negatively affect water availability and withdrawals as well as commodity prices and profit margins. This future climate variability could also influence the adoption of irrigation for crop production. The future availability of such water resources depends on how producers respond to evolving these environmental concerns. For example, agricultural producers can adopt many different best management practices (BMPs) that conserve water and soils. As such, it is valuable to gain insights into who is willing to adapt their current agricultural production practices in anticipation of an unclear future.

Farm conservation policy in the United States (US) started shifting in the late 1990s from set-aside programs such as the Conservation Reserve Program to focus conservation efforts on encouraging producers to adopt BMPs on working farmland (Cattaneo, 2003; Claassen, Cattaneo, and Johansson, 2008). The Environmental Quality Incentives Program (EQIP) was introduced in the Federal Agriculture Improvement and Reform Act of 1996 to partially reimburse producers for voluntarily adopting BMPs on working farmland (Aillery, 2006; Lichtenberg and Smith-Ramirez, 2011). The objective of working farmland programs is to maximize environmental benefits per dollar spent by targeting land that would produce the greatest environmental services from adopting BMPs without retiring farmland from production (Claassen, Cattaneo, and Johansson, 2008; Reimer and Prokopy, 2014).

Producers who choose to participate in these programs can select from a variety of BMPs to mitigate many different environmental concerns, but winter cover crops (EQIP Practice Code 340), no-tillage planting (referred to as no-till hereafter) (EQIP Practice Code 329), and irrigation water management (IWM) (EQIP Practice Code 449) are three BMPs that address important environmental concerns in the Southeast US. Winter cover crops are planted after the cash crop is harvested (typically fall) and terminated before the next cash crop is planted (typically spring). The primary purpose of winter cover crops is to reduce water-based soil erosion by covering bare soil over the winter (i.e., non-growing period) (Snapp et al., 2005). Other benefits generated by cover crops include increasing soil nitrogen levels (if a legume is planted), soil carbon storage, organic matter, soil moisture holding capacity, and weed control (Schipanski et al., 2014). No-till planting is a planting method that does not disturb the soil with tillage. No-till can also reduce soil erosion by accumulating residual plant biomass on the soil surface over the winter (Derpsch et al., 2010). IWM promotes water conservation by monitoring the volume, frequency, and rate of water used for irrigation. This BMP encompasses a broad set of actions such as recording irrigation use and timing, as well as the use of technologies such as soil moisture sensors (US Department of Agriculture Natural Resource Conservation Service (USDA NRCS), 2012).

Regardless of the cost-share payments and environmental benefits, adoption of cover crops, no-till, and IWM is in the US limited. Adoption of winter cover crops remains low, with only 3.2% of harvested land in the US managed under the BMP in 2012 (USDA National Agricultural Statistics Service (NASS), 2012). While more widely-practiced than cover crops, no-till has significant room for expansion, with approximately 23% of total US farmland planted using no-till (USDA NASS, 2012). The drivers of use BMPs are region specific. In the highly erodible Mississippi Portal, the USDA Region encompassing the majority of Middle and West Tennessee, 33% of cropland acreage is planted using no-till or strip till (USDA Economic Research Service (ERS), 2015) Since IWM includes a wide set of actions and technologies, there is limited knowledge of the number of acres following each individual action and/or using each technology that qualifies for the IWM program. However, USDA NRCS reported that over 450,000 acres received a cost-share payment for IWM in 2016 (USDA NRCS, 2017). In 2008, 7% of the total irrigated acres in the US were using more advanced irrigation technologies such as surface drip, sub-surface drip, and low-flow micro sprinklers (USDA NASS, 2008).

This thesis presents two separate studies focusing on BMP adoption by row crop producers in Middle and West Tennessee. The objective of the first study is to summarize results from a 2017 survey of Middle and West Tennessee row crop producers. Survey topics included producer perceptions regarding the benefits and costs associated with no-till, cover crops, and IWM. Respondent responsiveness to BMP cost-share payments and producer demographic information such as household income and age were also included as survey topics. Data gathered from this survey will help us better understand how to design effective conservation policies and get a better understanding of Tennessee producers' use of these BMPs.

The objective of the second study is to determine the effect of producer risk preference and other factors such as cost-share payments on willingness to adopt (WTA) cover crops and no-till using a risk preference elicitation method to measure producer risk preferences. Data from a 2017 survey of Middle and West Tennessee row crop producers was once again used. The results provide a better understanding of producer risk preferences and can guide future studies to measure and assess producer risk preferences.

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CHAPTER I 2017 MIDDLE AND WEST TENNESSEE ROW CROP PRODUCER SURVEY RESULTS

Abstract

This chapter presents a summary of results from a 2017 survey of Middle and West Tennessee row crop producers. Data gathered from this survey will further our understanding of the design of effective conservation policies and of Tennessee producers' use of no-till, cover crops, and irrigation water management (IWM). Most of the 344 survey respondents (87%) planted with no-till in 2016, which is considerably higher than the 29% of respondents who planted cover crops in 2016. Common reasons producers cited for not growing cover crops included expense and increased planting difficulty. All respondents were asked about factors posing difficulties to irrigating on their operation. The most common barriers to irrigation were installation expense, and field size and shape. Surveyed producers largely believed that no-till and cover crops would benefit soil quality/health, reduce erosion, and improve water quality. However, they were less sure about the likelihood of no-till and cover crops increasing yields and reducing yield variability.

Keywords: cost sharing, no-till, cover crops, irrigation water management, survey, Tennessee

Introduction

United States (US) farm conservation programs primarily concentrate on promoting the use of best management practices (BMPs) on working farmland (Cattaneo, 2003; Claassen, Cattaneo, and Johansson, 2008). Programs such as the Environmental Quality Incentives Program (EQIP) offer partial reimbursement for voluntarily adopted BMPs on working farmland (Aillery, 2006). Qualified producers can choose from a variety of BMPs to mitigate many different environmental issues such as soil erosion, soil carbon storage, organic matter, soil moisture holding capacity, water conservation, and weed control (Schipanski et al., 2014).

In Tennessee, winter cover crops (EQIP Practice Code 340), no-tillage planting (referred to as no-till hereafter) (EQIP Practice Code 329), and irrigation water management (IWM) (EQIP Practice Code 449) address important environmental concerns (US Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), 2017). Winter cover crops are planted after the cash crop is harvested (typically fall) and terminated before the next cash crop is planted (typically spring). This BMP can reduce water-based soil erosion by covering bare soil over the winter (i.e., non-growing period) as well as increase soil nitrogen levels (if a legume cover crop is planted), soil carbon storage, organic matter, soil moisture holding capacity, and weed control (Snapp et al., 2005; Schipanski et al., 2014). No-till planting does not disturb the soil with tillage, reducing soil erosion by accumulating residual plant biomass on the soil surface over the winter (Derpsch et al., 2010). The purpose of IWM is to promote water conservation by monitoring the volume, frequency, and rate of water used for irrigation. IWM includes a wide set of actions such as recording irrigation use and timing as well as the use of technologies such as soil moisture sensors (USDA NRCS, 2012).

Adoption of cover crops, no-till, and IWM in the US has been low despite the availability of cost-share payments and potential environmental benefits. Winter cover crop adoption in the US is around 3.2% of harvested farmland in 2012 (USDA National Agricultural Statistics Service (NASS), 2012). While more widely-adopted than winter cover crops, no-till still has significant room for expansion, with approximately 23% of total US crop land planted using no-till in 2012 (USDA NASS, 2012). Since IWM includes a wide set of actions and technologies, there is limited knowledge of the number of acres following each individual action and/or using each technology that qualifies for the IWM program. However, USDA NRCS reported that over 450,000 acres received a cost-share payment for IWM in 2016 (USDA NRCS, 2017). In 2008, 7% of the total irrigated acres in the US were using more advanced irrigation technologies such as surface drip, sub-surface drip, and low-flow micro sprinklers (USDA NASS, 2008).

The objective of this chapter is to present results from a 2017 survey of Middle and West Tennessee row crop producers (Appendix B), offering insights into perceptions regarding the benefits and costs associated with no-till, cover crops, and IWM, responsiveness to BMP cost-share payments, and producer demographic information such as household income and age. Data gathered from this survey will inform policy makers and Extension agents on use of BMPs in Middle and West Tennessee.

Survey Data

Following Dillman's (2007) mail survey total design method recommendations, a postcard (Appendix C) was first mailed on January 26, 2017 to inform row crop producers that they would soon be receiving the full Middle and West Tennessee row crop producer survey. The first round of mail surveys was sent out on February 8, 2017. A prepaid postage envelope was included, as well as a cover letter (Appendix D) explaining the purpose of the survey and an insert (Appendix E) detailing the benefits and requirements of winter cover crops, no-till, and IWM. A reminder postcard (Appendix F) was sent out on February 17, 2017, followed by a second round of questionnaires on March 8, 2017. A third and final round of surveys was mailed in July 2017. The survey was initially mailed to 5,184 addresses of individuals who received Farm Service Agency (FSA) payments from 2012-2016.Declines to participate, undeliverable addresses, and replies that the recipient does not farm reduced the survey pool to 3,84l. A total of 344 responses to the mail survey were received, resulting in a 9% response rate.

The survey included six sections, with the first including questions about acreage farmed, crop yields, and production costs. The second, third, and fourth sections covered questions on no-till, cover crops, and IWM; respectively. The fifth and sixth sections of the survey solicited information on producer demographics including age, education, and income.

The average age of survey respondents was 64 years old, which is slightly older than the average age of principal operators in the state (59 years old in 2012) (USDA NASS, 2012). Approximately 41% of producers surveyed had a college degree or equivalent. Roughly half of respondents had a total of farm and non-farm income for 2016 of less than $99,999, and roughly 5% of respondents reported their 2016 income to be $500,000 or above (Figure 1). Over half of respondents, 184 of 319 (58%), were enrolled in crop insurance in 2016 (Table 1). According to USDA Risk Management Agency (RMA) reports for Tennessee, 82% of corn acreage, 91% of cotton acreage, 83% of soybean acreage, and 76% of wheat acreage were insured in 2016 (USDA RMA, 2016). One possible explanation of our result is the difference between number of respondents and the percentage of acres.

Overview of Middle and West Tennessee Row Crop Operations

Soybeans were the most planted crop among respondents, followed by corn, wheat, and then cotton (Table 2), which is consistent with the prevalence of planted acreage by crop statewide (USDA NASS, 2017) (Table 3). The majority of soybeans were produced on dryland acres with the average size of 388 acres of soybeans per participating operation (Table 2) and average yield of 43 bushels per acre (Table 4). For producers who did irrigate soybeans, the average operation size was 483 acres (Table 2), and they reported an average yield of 55 bushels per acre (Table 4). Most respondents reported that their dryland soybean costs of production were between $100 and $199 per acre, excluding any land rent costs (Figure 2). A majority of those irrigating their soybeans said their production costs were $200 to $299 per acre (Figure 2).

Dryland corn was produced by 152 respondents in 2016, and 33had irrigated corn acreage (Table 2). Of operations with dryland corn, the average dryland corn acreage was 267 acres, and irrigated corn farms averaged 328 acres (Table 2). Yields averaged 140 bushels per acre and 197 bushels per acre for dryland and irrigated corn, respectively (Table 4). Production costs of dryland corn were most commonly reported between $300 and $399 per acre, while irrigated corn costs of production were said to be closer to between $400 and $499 per acre (Figure 3).

Less than 100 respondents (96 producers) said they produced dryland wheat, with the average size of a dryland wheat operation being 232 acres (Table 2). Only six respondents reported growing irrigated wheat in 2016 with an average farm size of 432 acres (Table 2). Those who were growing irrigated wheat were likely double cropping, with irrigation technologies primarily installed for the spring planted crop. Dryland wheat yield averaged 67 bushels per acre, and the six respondents who had irrigated wheat acreage reported an average yield of 78 bushels per acre (Table 4). The cost of production for dryland wheat was between

$150 and $199 per acre for 35% of the respondents and between $200 and $249 per acre for 30% of the respondents (Figure 4). Irrigated costs of production for wheat was not collected.

Forty-nine producers surveyed said they grew dryland cotton, and 10 irrigated cotton in 2016 (Table 2). Average acreage for dryland cotton was 372 acres, while average irrigated cotton acreage was higher at 460 acres (Table 2). Survey respondents reported an average yield of 909 pounds per acre for dryland cotton and 1,058 pounds per acre for irrigated cotton (Table 4). Production costs for dryland cotton ranged from $300 to $399 per acre for 42% of the respondents, and irrigated cotton costs were reported to be less than $399 per acre for the majority of question respondents (Figure 5).

Herbicide Resistant Weeds

Most respondents (69%) had identified herbicide resistant weeds on their operation. The earliest reported herbicide resistant weeds are in 1999, with a sharp increase in cases reported around 2010 (Figure 6). With the majority of producers reporting the presence of herbicide resistant weeds on their operation, it is likely this will continue to be a topic of growing concern and interest.

No-Till

Only 21% of the survey respondents said they knew the cost of no-till could be partially reimbursed by the USDA NRCS. Of the respondents who were aware of the existence of a cost-share program, only 16 (~33%) reported receiving a cost-share payment for no-till (Table 5). However, 260 out of 300 producer responses to the survey (87%) said they planted with no-till (Table 4), which is higher than USDA NASS's (2016) report that 75.9% of Tennessee acreage was planted using no-till in 2016. The adoption of no-till was reported to be in as early as 1948 and as recent as 2015 (Figure 7). Respondents using the BMP reported having an average of 605 no-till acres (Table 5).

Respondents were asked about their opinion regarding the likelihood of a variety of outcomes occurring as a result of using no-till on their operation. Queried outcomes were increased yield, reduced yield variability, retained soil moisture, reduced erosion, reduced cost, weed control, improved soil quality/health, improved water quality, and increased management burden. On average, respondents seemed to believe there was a high likelihood of improved soil health and erosion reduction as a result of no-till. Those surveyed were less optimistic about no-till's ability to reduce weeds, increase yield, and reduce yield variability (Figure 8).

Cover Crops

Approximately half of the respondents indicated they were aware the costs of cover crops may be partially reimbursed by the NRCS. Of the respondents who were aware a cover crop cost-share program existed, 53 (49%) indicated they had previously received a cost-share payment for cover crops (Table 5).

University of Tennessee Extension reported that 22% of Tennessee row crop acreage was planted after a cover crop in 2015 (University of Tennessee Institute of Agriculture, 2015). Based on the 2017 survey, 29% of the respondents said they planted cover crops in 2016, 22% said they did not plant cover crops in 2016 but had previously, and 49% said they had never used cover crops (Table 5). Cover crop usage averaged 269 acres of land per participating operation (Table 4). Several cover crop varieties were reportedly used by surveyed producers, with 65 respondents saying they planted wheat, 43 planted rye, 29 planted radish, 28 planted clover, 15 planted oats, ten planted turnips, six planted vetch, and three planted rapeseed (Figure 9).

Respondents who had previously grown cover crops but stopped using the BMP were asked what prompted the discontinuation. Reasons surveyed included too expensive, made planting difficult, reduced yields, too complicated, and tough to terminate. The most common reasons for stopping cover crop application were reported to be increased planting difficulty, with 26 responses and too expensive, with 24 responses (Figure 10). Respondents were permitted to select more than one reason for stopping the use of the BMP.

Respondents were asked about their perception of the likelihood of increased yield, reduced yield variability, retained soil moisture, reduced erosion, increased profit, weed control, improved soil quality/health, improved water quality, and increased planting difficulty to occur from the planting of cover crops. Producers largely believed reduced erosion, improved soil quality/health, and improved water quality were likely to occur as a result of using cover crops. A high percentage of producers said they had no idea of the impact cover crop adoption would have on increased yield or reduced yield variability (Figure 11).

Irrigation Water Management

Only 30 out of 274 respondents (11%) said they knew the costs of IWM may be partially reimbursed by the USDA, substantially fewer than those who were aware of no-till and cover crop cost-share payment programs. Of the 30 respondents who knew of the cost-share program availability, none reported ever receiving a cost-share for IWM (Table 5).

Though none reported receiving cost-share assistance for IWM, 42 out of 273 respondents to the question (15%) reported that they irrigated (Table 5), with the earliest report of irrigation being 1988 and the most recent being 2017 (Figure 12). In the state of Tennessee, 146,932 of 823,932 (18%) acres on operations using irrigation to some extent were irrigated in 2013, but not necessarily using more advanced IWM technologies (USDA NASS, 2013). Based on this figure roughly 5% of all Tennessee row crop acreage is irrigated (USDA FSA, 2017) Knowledge regarding the number of acres following each individual action and/or using each technology that qualifies for the IWM program is limited, as IWM includes a wide variety of actions and technologies.

Producers who irrigated were asked about their primary water source for irrigation, with 40 respondents saying a well was their primary source with an average depth of about 200 feet. No irrigators reported having a river/stream or lake as their primary irrigation water source, and two respondents said their irrigation water source was a farm pond (Figure 13). Center pivot was by far the most common type of irrigation system among producers surveyed, with 38 of the 42 irrigators (90%) using the practice, followed by furrow (three respondents), traveling gun (two respondents), and subsurface drip (2 respondents) (Figure 14). Respondents could select more than one irrigation technology if multiple were in use on their operation. The power source used for irrigation is primarily electricity (31 of the 42 total irrigators or 74%), followed by diesel (74%) and natural gas (5%) (Figure 15).

Respondents who irrigated were asked to select the method(s) they used to determine when to irrigate from a menu of options consisting of water balance, soil moisture sensors, plant status, consultant, growth stage, neighbor irrigated, and a schedule. Growth stage, soil moisture sensors, and plant status were the most frequently reported factors in the irrigation timing decision (Table 6). The 42 respondents who irrigated were asked how much water (inches per acre) they usually applied when irrigating corn, cotton, and soybeans (Table 7). Corn was the most commonly irrigated crop, and 27 of the 36 reporting corn irrigators (75%) said they apply 0.25” – 0.50” inches per acre when they irrigate the crop. Of the 11 respondents who irrigated cotton, roughly half apply 0.25” – 0.50” inches per acre, with another 45% applying 0.51” –

0.99” inches per acre. There are 35 question respondents reporting irrigating soybeans, with 66% applying between 0.25” – 0.50” inches per acre per application.

Respondents who irrigated were asked their opinion on the likelihood of achieving higher yields, reduced yield variability, increased profit, securing an operating loan, and lower crop insurance costs to occur from using IWM on their farm. Respondents were confident that the use of IWM would increase yields, reduce yield variability, and increase profit. However, few producers thought IWM would increase the likelihood of securing an operating loan or lower their crop insurance costs (Figure 16).

All respondents, including non-irrigators, were asked a question regarding the challenges to irrigating on their operation. Producers were offered a menu of potential challenges consisting of field slope, field shape, water quality, water availability, field size, installation expense, existing debt, loan availability, time and effort needed, uncertain commodity prices, and uncertain energy costs. Respondents were permitted to select more than one factor they considered a challenge to irrigation. 240 responded to the question, and the most commonly cited challenges were installation expense (149 responses), field size (143 responses), and field shape (137 responses) (Figure 17).

Implications and Conclusions

Most producers (87%) reported using no-till in 2016, but only 21% of respondents were aware the USDA may partially reimburse the costs of no-till adoption, and 28% of those who were aware of the program reported receiving a USDA cost-share payment. Just under one third (29%) of survey respondents planted cover crops in 2016, and an additional 22% had planted cover crops in the past but did not in 2016. Common reasons cited for the discontinuation of cover crop planting included increased planting difficulty and too expensive. About half (52%)

of respondents were aware the costs of cover crop adoption may be partially reimbursed by the USDA, and roughly half of those who knew USDA cost-share assistance was available reported participating in the cost-share program. Increases in cost-share amount offered for cover crop adoption were found to consistently increase adoption rates of the BMP. Knowledge of IWM USDA cost-share assistance was low, with only 11% of respondents reporting awareness. Furthermore, no producers reported having ever received USDA cost-share assistance for IWM. Data gathered from this survey will help us further understand how to design effective conservation policies and to get a better understanding of Tennessee producers' use of no-till, cover crops, and IWM.

Based on survey results, no-till adoption rates do not dramatically improve given higher cost-share payments. As few producers were aware USDA cost-share assistance was available for IWM, increased program advertising may improve adoption rates in the region.

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Appendix A Tables and Figures

Table 1. Surveyed Producer Demographics

Factor	Value
Age (average in years)	64
College degree (percent holding)	41%
Crop insurance (percent enrolled)	57.68%

Table 2. Number of Operations and Acreage Distribution for Relevant Operations by Crop

Crop	Number of operations	Mean (acres)	Minimum (acres)	Maximum (acres)
Soybeans – dry	238	388	3	4,000
Soybeans – irrigated	30	483	50	2,500
Corn – dry	152	267	1	3,080
Corn – irrigated	33	328	50	1,800
Wheat – dry	96	232	2	1,900
Wheat – irrigated	6	432	35	1,600
Cotton – dry	49	372	1	2,000
Cotton – irrigated	10	460	24	2,000

Table 3. 2017 USDA Reports of Tennessee Planted Acreage and Average Yield by Crop

Crop	Planted Acres	Average Yield
Soybeans	1,580,048	50 (bu/acre)
Corn	822,142	171 (bu/acre)
Wheat	348,160	70 (bu/acre)
Cotton	251,959	1,031 (lb/acre)

Sources: USDA NASS, 2017 & USDA FSA, 2017

Table 4. Yield Summary for Survey Respondents

Crop	Minimum	Mean	Maximum
Dryland corn (bu/ac)	107 (n = 150)	140 (n = 145)	175 (n = 155)
Irrigated corn (bu/ac)	171 (n = 34)	197 (n = 35)	236 (n = 35)
Dryland cotton (lbs/ac)	726 (n = 39)	909 (n = 39)	1107 (n = 41)
Irrigated cotton (lbs/ac)	1046 (n = 7)	1058 (n = 7)	1356 (n = 7)
Dryland soybeans (bu/ac)	50 (n = 208)	43 (n = 196)	82 (n = 216)
Irrigated soybeans (bu/ac)	46 (n = 30)	55 (n = 29)	67 (n = 30)
Dryland wheat (bu/ac)	64 (n = 98)	67 (n = 93)	90 (n = 101)
Irrigated wheat (bu/ac)	65 (n = 1)	78 (n = 1)	91 (n = 1)

Table 5. Cost-share Program Awareness and Adoption of BMPs

	No-till	Cover crops	IWM*
Aware of USDA cost-share assistance	21% (n = 298)	52% (n = 307)	11% (n = 274)
Received cost-share assistance (of those who were aware of program)	28% (n = 57)	49% (n = 108)	0% (n = 30)
Received cost-share assistance (of all respondents)	5% (n = 344)	15% (n = 344)	0% (n = 344)
Currently using BMP	87% (n = 300)	28% (n = 300)	-
Used BMP in past but did not in 2016	-	22% (n = 300)	-
Have never used BMP	-	49% (n = 300)	-
Acreage enrolled in BMP (average)	605 (n = 215)	268 (n = 82)	-

*Irrigation water management

Table 6. Prevalence of Factors Used to Determine when to Irrigate

Factor	Percentage Citing (n = 42)
Water balance	21%
Growth stage	43%
Soil moisture sensors	48%
Neighbor irrigated	14%
Plant status	52%
A schedule	0%
Consultant	21%

Table 7. Amount of Water (in/ac) Applied to Corn, Cotton, and Soybeans

Amount Applied Per Application (in/ac)	Number of Respondents		
	Corn (n = 36)	Cotton (n = 11)	Soybeans (n = 35)
Less than 0.25”	6%	0%	11%
0.25”-0.50”	75%	45%	66%
0.51”-0.99”	14%	45%	17%
1-1.49”	0%	0%	0%
1.5-1.99”	3%	0%	3%
2-2.49”	3%	9%	3%
More than 2.49”	0%	0%	0%

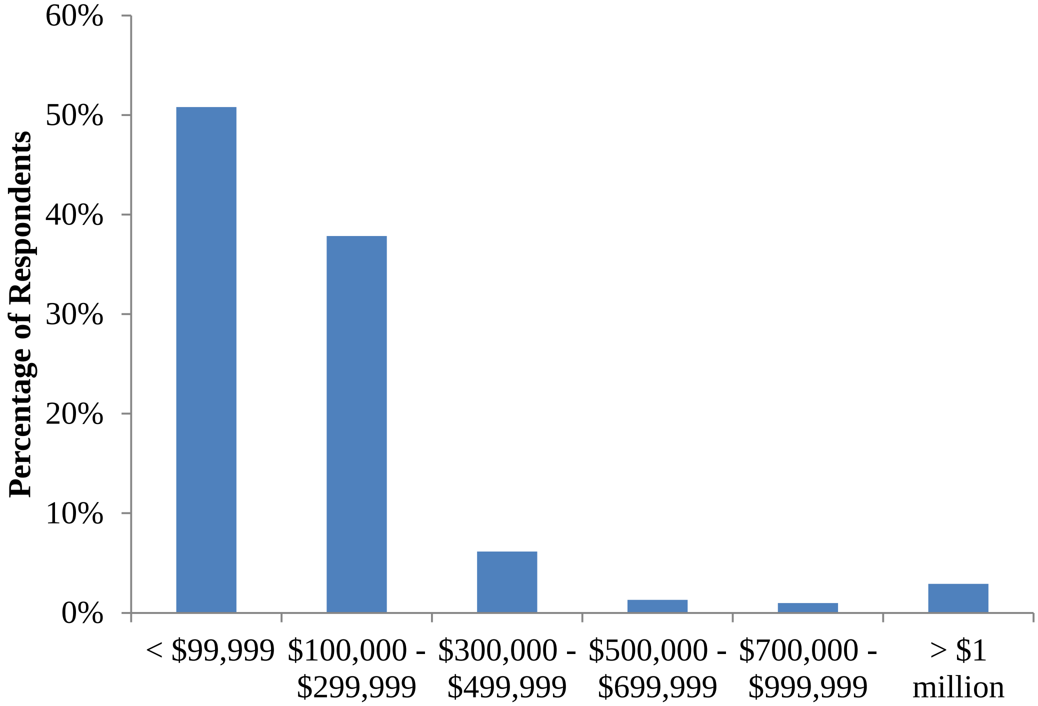

Figure 1. 2016 Farm and Non-Farm Household Income Categories (n = 309)

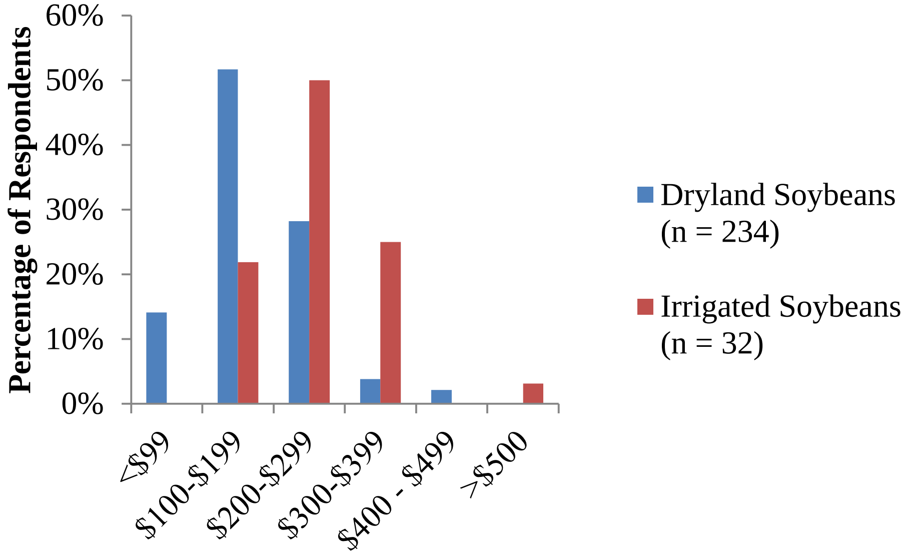

Figure 2. Per Acre Production Cost of Dryland and Irrigated Soybeans

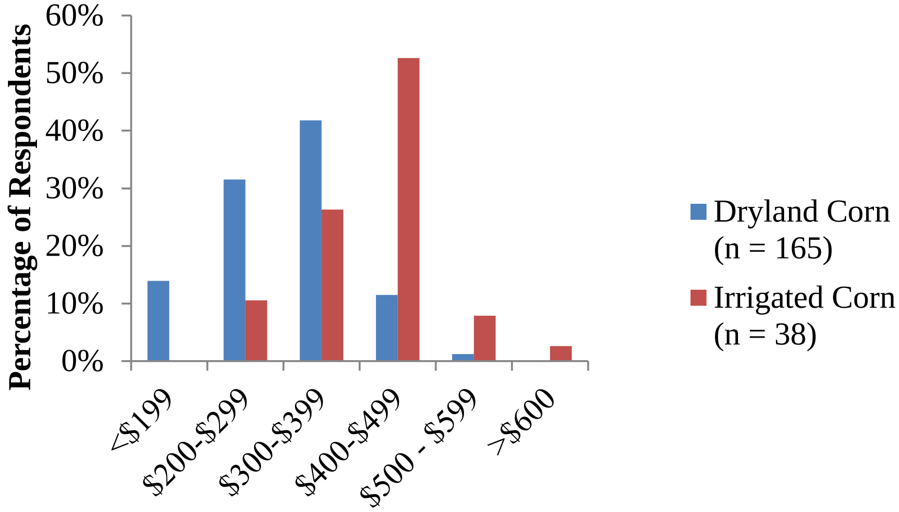

Figure 3. Per Acre Production Cost of Dryland and Irrigated Corn

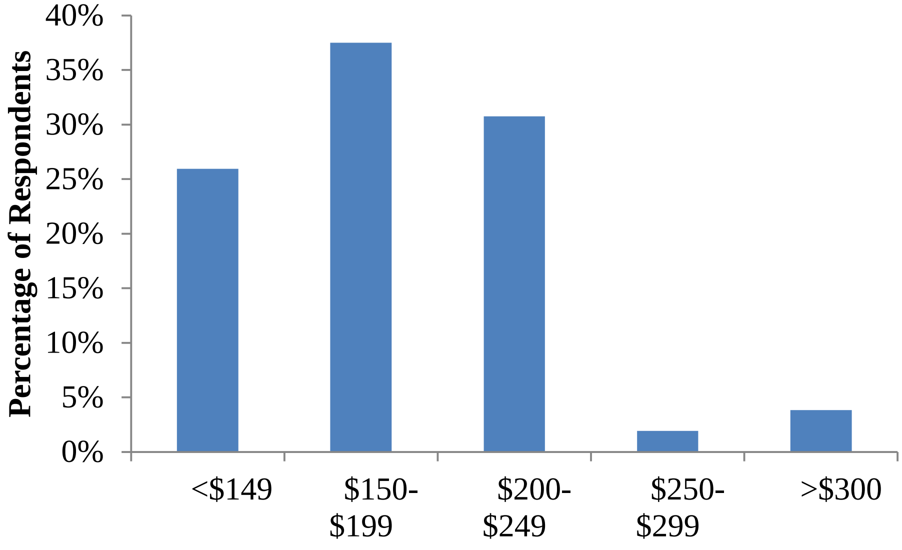

Figure 4. Per Acres Production Costs of Dryland Wheat (n = 104)

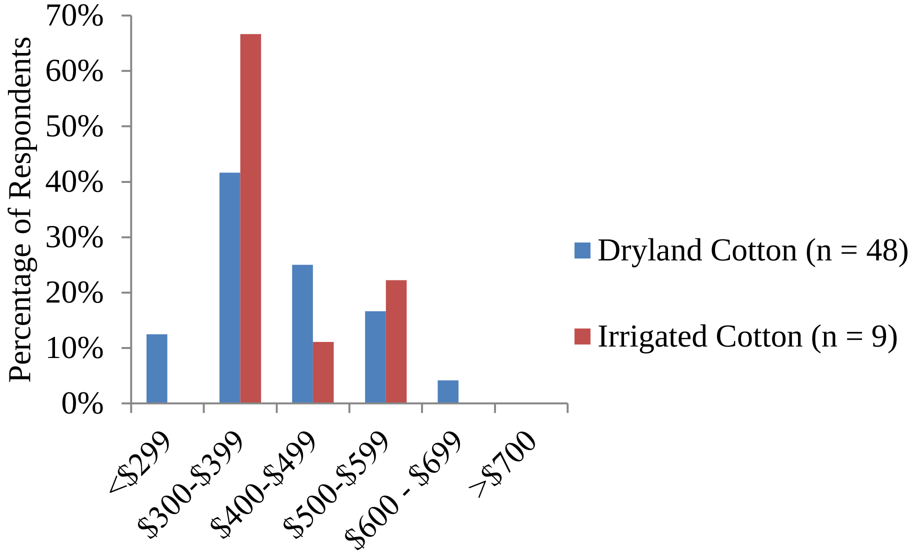

Figure 5. Per Acres Production Costs of Dryland and Irrigated Cotton

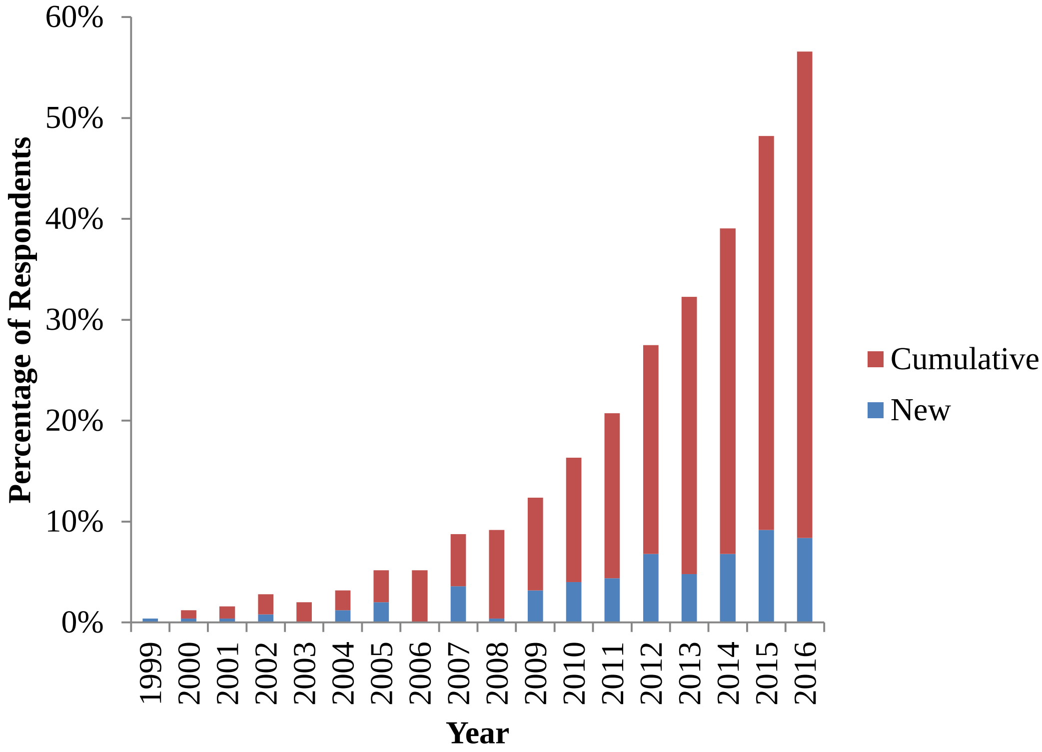

Figure 6. New and Previous Identifications of Herbicide Resistant Weeds (n = 251)

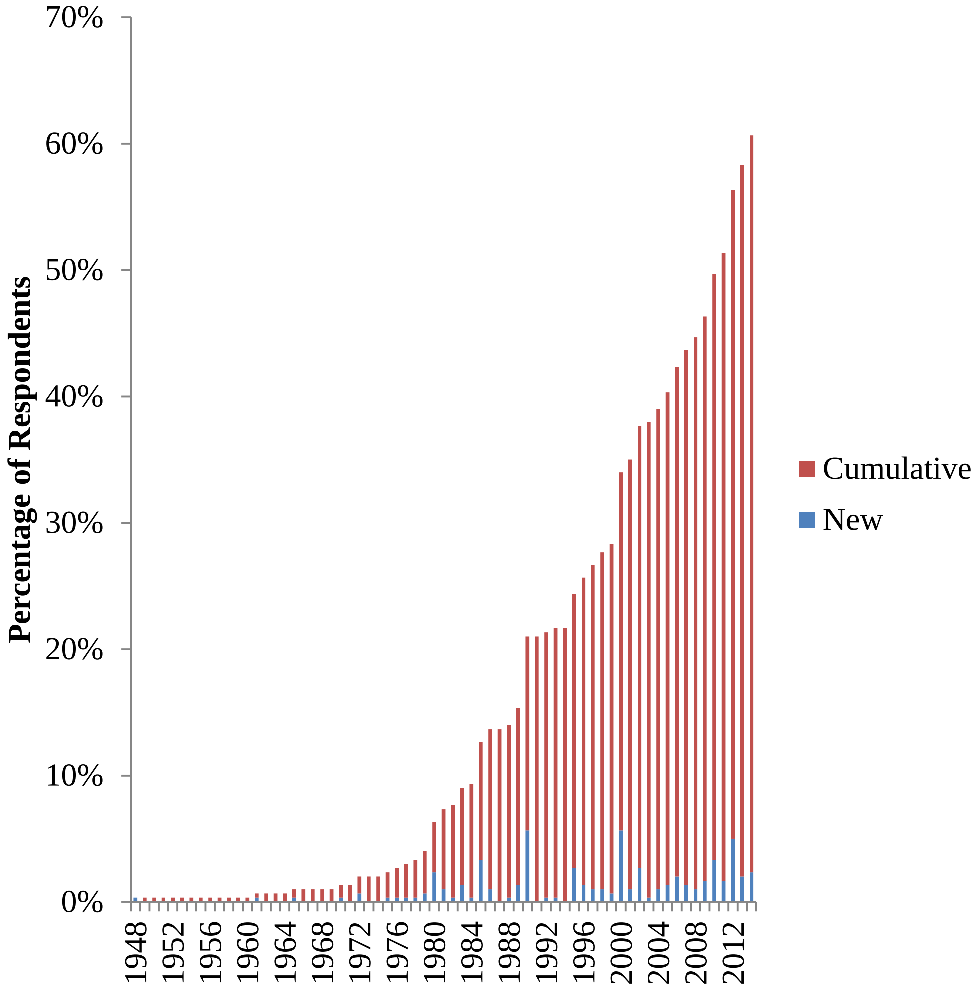

Figure 7. New and Cumulative Adoption of No-Till by Year

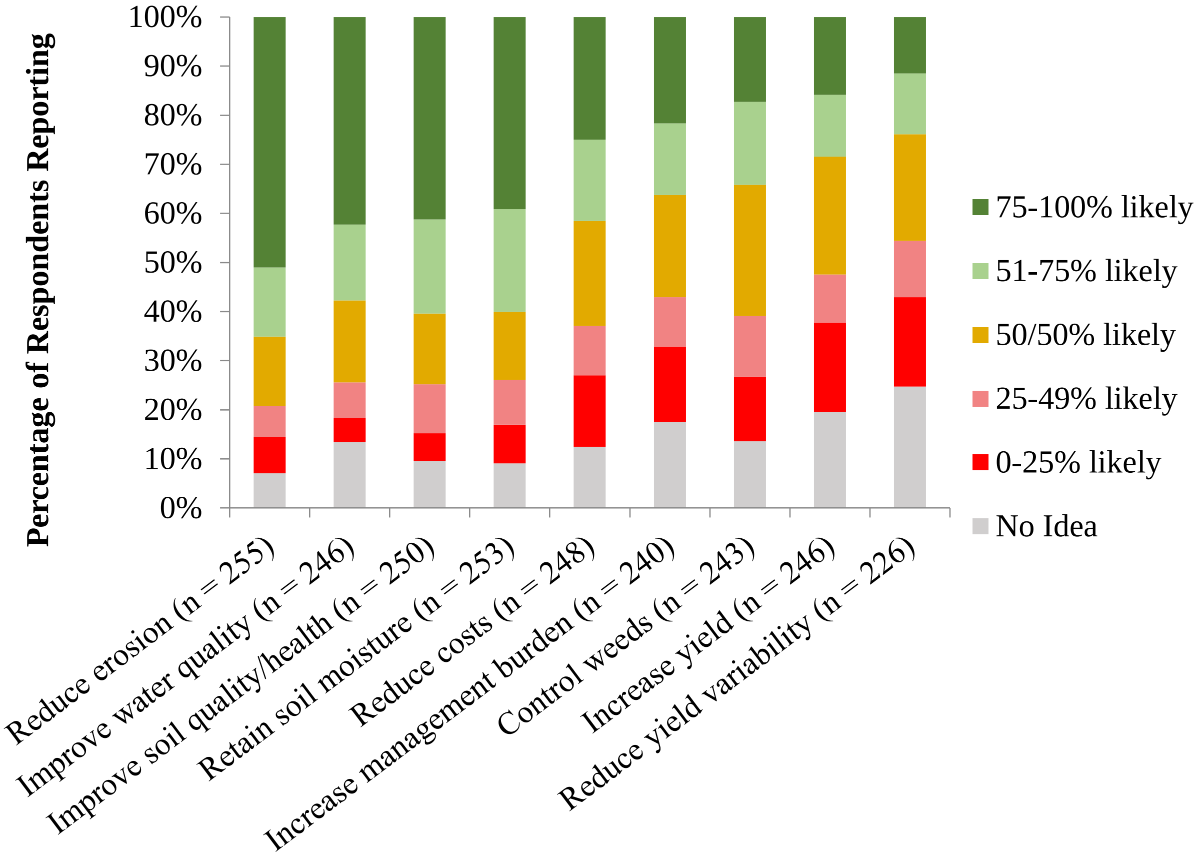

Figure 8. Respondent Perceptions Regarding the Likelihood of Outcomes to Occur as a Result of No-till Adoption

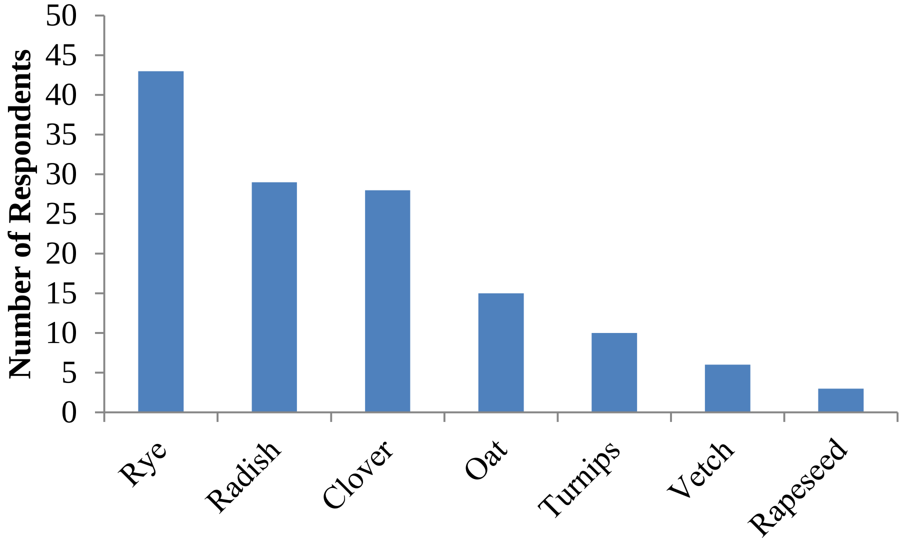

Figure 9. Commonly Reported Cover Crop Varieties (n = 80)

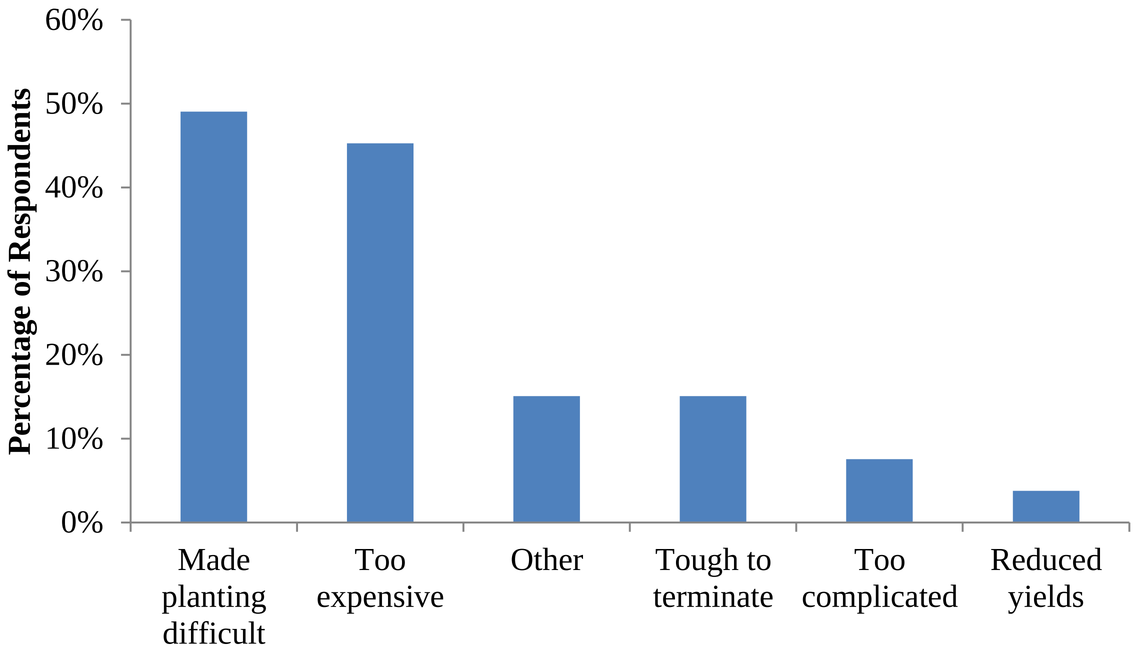

Figure 10. Reasons for Cover Crop Discontinuation (n = 53)

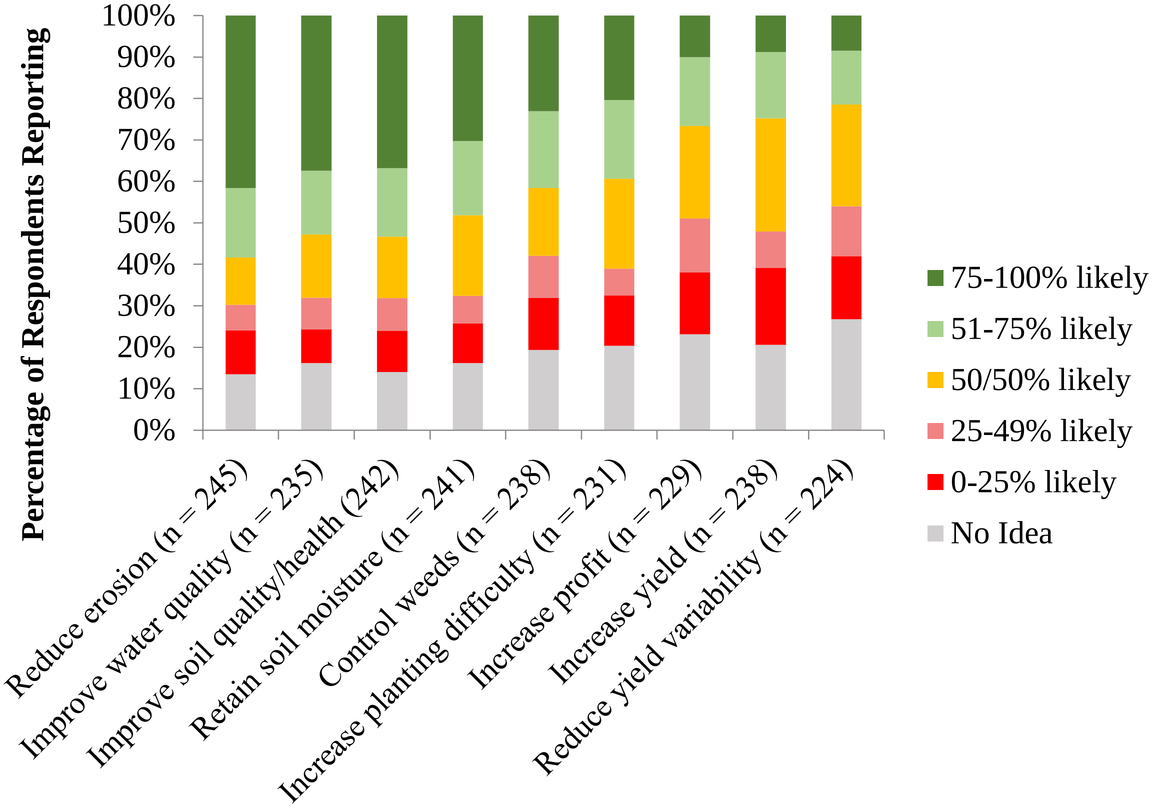

Figure 11. Respondent Perceptions Regarding the Likelihood of Outcomes to Occur as a Result of Cover Crop Adoption (n = 238)

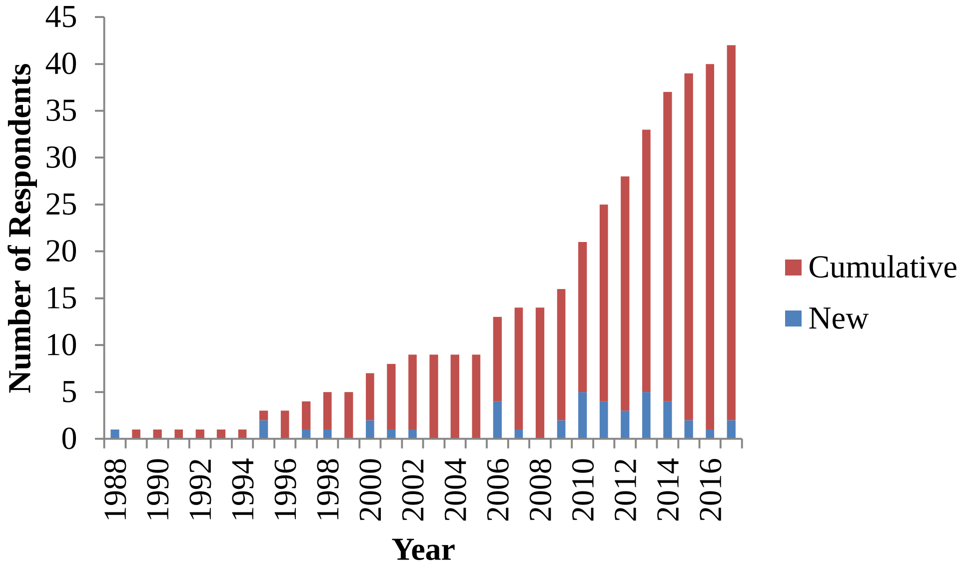

Figure 12. Number of New and Cumulative Reported Irrigation Adopters by Year (n = 42)

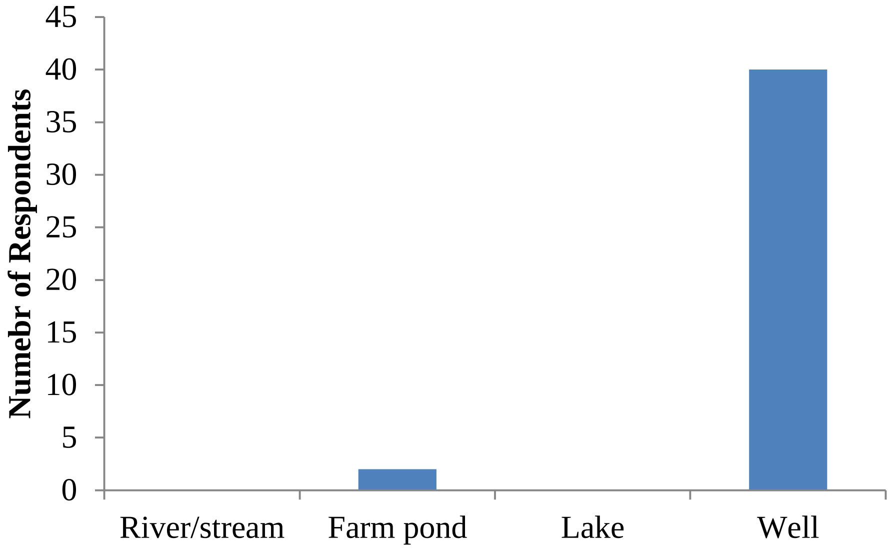

Figure 13. Primary Source of Irrigation Water (n = 42)

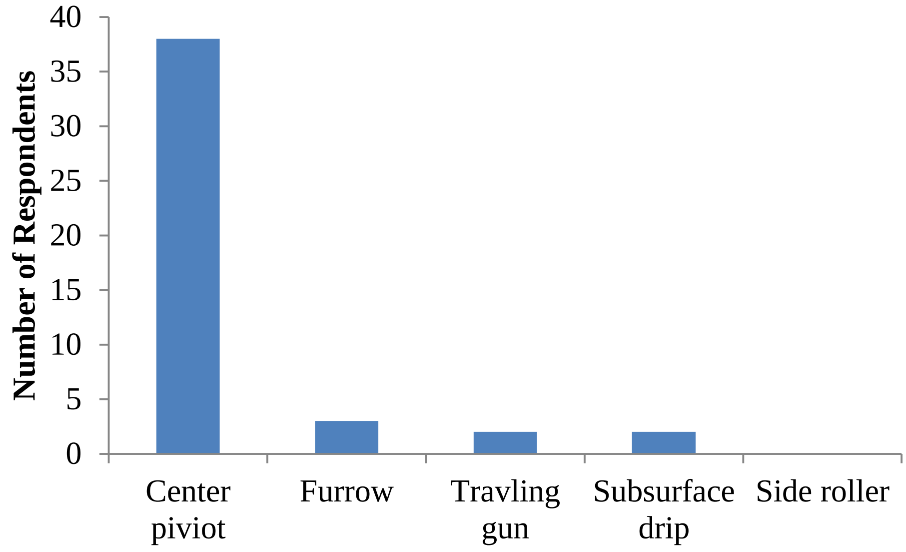

Figure 14. Utilized Irrigation Technologies (n = 42)

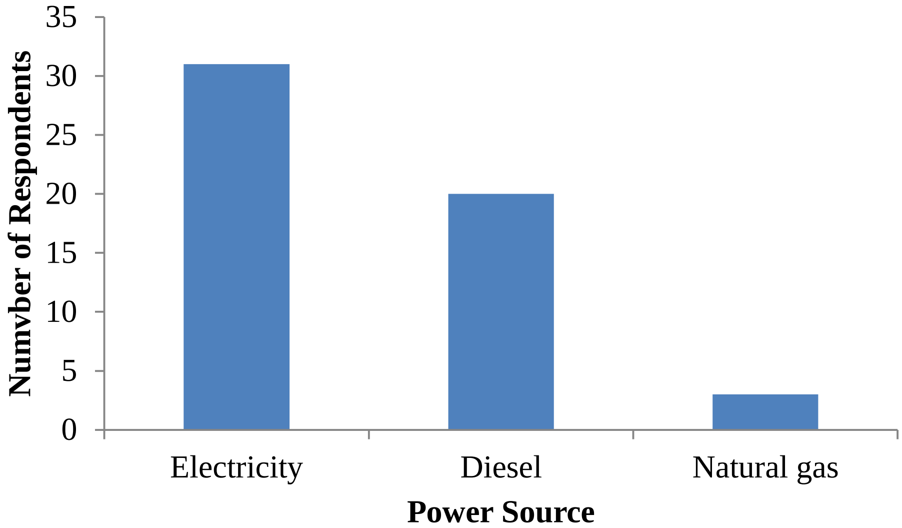

Figure 15. Utilized Power Sources for Irrigation (n = 41)

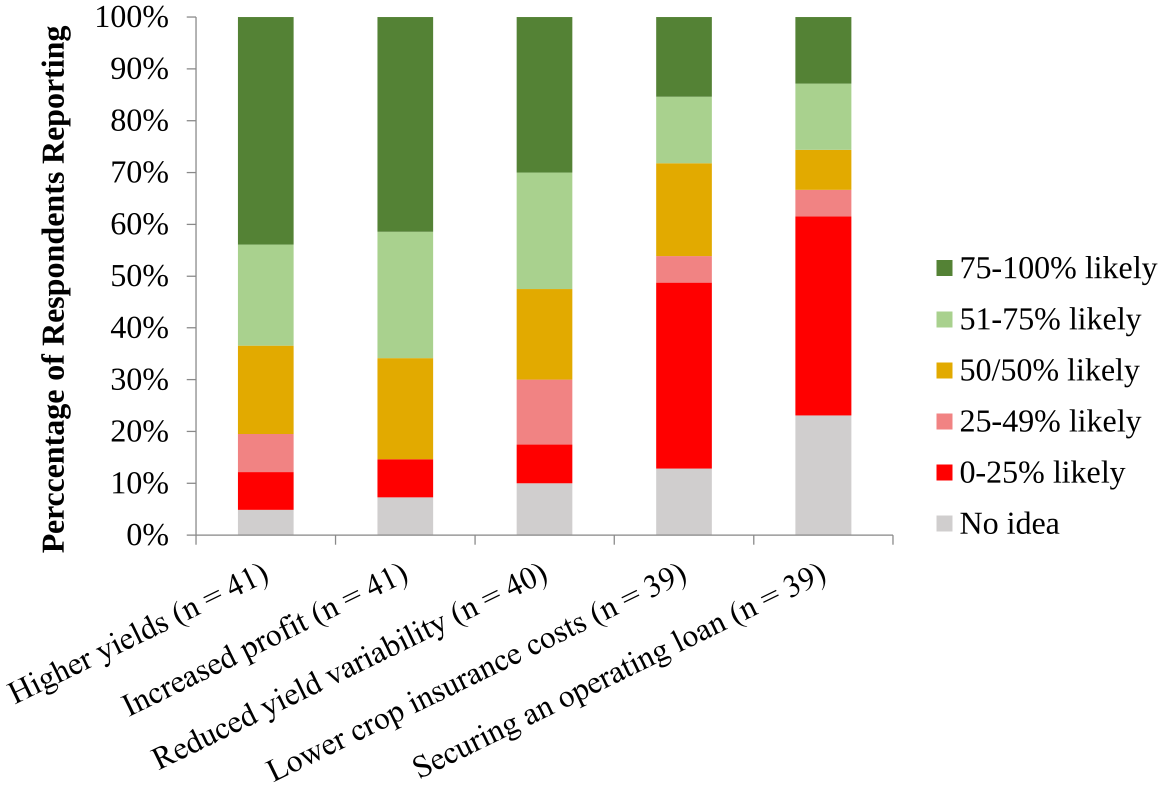

Figure 16. Respondent Perceptions Regarding the Likelihood of Outcomes to Occur as a Result of IWM Adoption

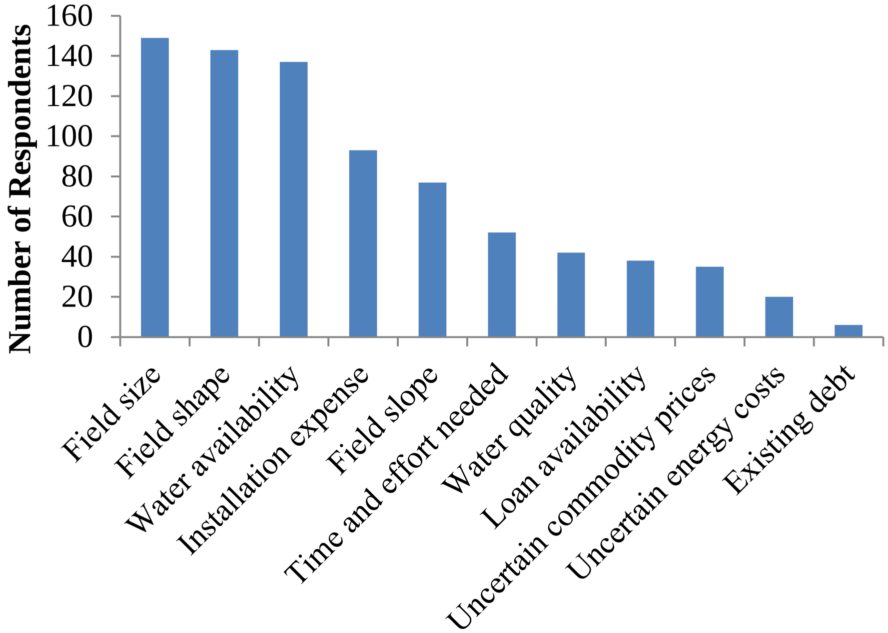

Figure 17. Factors Posing Challenges to Irrigation (n = 240)

Appendix B Full 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.

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

Q4. **<u>Excluding land rent cost only</u>**, **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? _________ ac

Cover 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 →					
	0-25%	**25-49%**	**50/50%**	**51-75%**	**75-100%**	**No Idea**
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--------- *ADOPT* the technology, and you have a 50/50 chance of: *DECREASING* your farm income by:		*INCREASING* your farm income by:	*DO NOT ADOPT*, and your farm income is:	Would you adopt this technology? (Please check one box in each row) *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

Appendix C Pre-Survey Postcard

Dear Crop Producer:

In the coming week, you will be receiving a survey in the mail regarding the adoption of best management practices (BMPs) such as cover crops, no-till, and efficient irrigation use on your farm. Information from this study will be helpful for policymakers to understand producers' view on BMPs and how to create policy to encourage the adoption of BMPs.

The survey should take about *15 minutes* to complete. Participation is voluntary. We will keep your information confidential. Data will be stored securely and made available only to researchers conducting the study, unless you provide written permission to do otherwise. No reference will be made in any reports that could link you to your information.

You may decline to participate in this survey without penalty. If you do participate, you may withdraw from the study at any time without penalty or loss of benefits. If you choose to withdraw from the study before data collection is completed, your data will be destroyed.

If you have questions about your rights as a survey participant, contact the UT Institutional Review Board Staff at utkirb@utk.edu or (865) 974-7697. Please contact us if you have any other questions about the survey. Thank you for taking time out of your busy schedule to help us!

Dr. Christopher Boyer
cboyer3@utk.edu, Phone: 865-974-7468
Department of Agricultural & Resource Economics
UT Institute of Agriculture, The University of Tennessee Knoxville

Appendix D Survey Cover Letter

West & Middle Tennessee Row Crop Producer Survey

Dear crop producer:

We **invite you to participate in a study conducted by University of Tennessee Institute of Agriculture researchers.** Information from this study will be helpful for understanding why row crop producers in your region use certain management practices. We are also interested in understanding how you cope with the riskiness of crop production. **Please have the farm's primary decision maker answer the survey. Even if you are not farming, we would like you to return the survey and indicate only that you are not farming.**

The survey should take about 15 minutes to complete. Your participation is voluntary. We will keep your information confidential. Data will be stored securely and made available only to researchers conducting the study, unless you provide written permission to do otherwise. No reference will be made in any reports that could link you to your information.

You may decline to participate in this survey without penalty. If you do participate, you may withdraw from the study at any time. If you choose to withdraw from the study before data collection is completed, your data will be deleted and responses destroyed.

If you have questions about your rights as a survey participant, contact the UT Institutional Review Board Staff at utkirb@utk.edu or (865) 974-7697. Please contact us if you have any other questions about the survey. Thank you for taking time out of your busy schedule to help us!

Dr. Aaron Smith
aaron.smith@utk.edu
865-974-7476
Department of Agricultural & Resource Economics
UT Institute of Agriculture, The University of Tennessee Knoxville

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CONSENT

I have read the above information. I have received
a copy of this form. Return of the completed survey constitutes my consent to participate.

Appendix E Insert Included in Survey

COVER CROPPING

This practice involves planting grasses, legumes, and herbs between successive production crops.

Benefits

- Reduce erosion from wind and water
- Increase soil organic matter content
- Suppress weeds
- Manage soil moisture

Actions Required

- Establishing cover crop species between successive production crops that will not compete with production crop yield or harvest
- Cover crops may be grazed or hayed

Termination of cover crops will occur before planting the successive production crop

NO-TILL MANAGEMENT

No-till maintains the amount, orientation, and distribution of crop and other plant residue on the soil surface year round. Soil-disturbing activities are limited to those necessary to place nutrients, condition residue and plant crops.

Benefits

- Reduce soil erosion
- Improve soil organic matter content
- Increase plant-available moisture

Actions Required

- No full-width tillage is performed from the time of harvest or termination of one cash crop to the time of harvest or termination of the next cash crop.

Crop seed is placed in a narrow strip with a coulter or disk opener

IRRIGATION WATER MANAGEMENT

Irrigation water management is the process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner.

Benefits:

- Optimizes available water supplies
- Increases crop yields
- Increases profitability
- Reduce energy use

Actions Required

- Record keeping of irrigation use and timing
- Method for determining the flow rate or volume of irrigation
- Documentation of the method used for scheduling the timing and amount of irrigation

Collect and use data from soil moisture sensors to schedule irrigation

Appendix F Survey Reminder Postcard

Dear Crop Producer:

We recently mailed you a survey regarding the adoption of best management practices (BMPs) such as cover crops, no-till, and efficient irrigation use on your farm. If you have completed the survey, we would like to take this opportunity to thank you. If not, you are invited to participate in the research study we are conducting on use and adoption of BMPs on your farm. Information from this study will be helpful for policymakers to understand producers' view on BMPs and how to create policy to encourage the adoption of BMPs.

The survey should take about *15 minutes* to complete. Participation is voluntary. We will keep your information confidential. Data will be stored securely and made available only to researchers conducting the study, unless you provide written permission to do otherwise. No reference will be made in any reports that could link you to your information.

You may decline to participate in this survey without penalty. If you do participate, you may withdraw from the study at any time without penalty or loss of benefits. If you choose to withdraw from the study before data collection is completed, your data will be destroyed.

If you have questions about your rights as a survey participant, contact the UT Institutional Review Board Staff at utkirb@utk.edu or (865) 974-7697. Please contact us if you have any other questions about the survey. Thank you for taking time out of your busy schedule to help us!

Dr. Christopher Boyer
cboyer3@utk.edu, Phone: 865-974-7468
Department of Agricultural & Resource Economics
UT Institute of Agriculture, The University of Tennessee Knoxville

CHAPTER II THE EFFECT OF PRODUCER RISK PREFERENCE ON WILLINGNESS TO ADOPT COVER CROPS AND NO-TILL

Abstract

The objective of this chapter is to determine the impact of producer risk preference and other factors such as cost-share payments on willingness to adopt cover crops and no-till using a risk preference elicitation method to measure producers risk preferences. Probit regressions where used to estimate the cover crop and no-till adoption models. A double-bounded tobit regression was used to model producer risk preference. Producer education and age were significant predictors of producer risk preferences, but crop insurance enrollment was not found to be a predictor of producer risk preference It was found that more producers would plant cover crops if the cost-share payment increased; however, producers were not responsive to cost-share payments for no-till. The sign of the constant relative risk aversion coefficient was significant and negative for cover crop and no-till adoption, with risk averse producers less likely to adopt either practice.

Keywords: cost sharing, cover crops, no-till, lottery choice, risk, bivariate probit, tobit

Introduction

United States (US) farm conservation policy shifted in the late 1990s from removing farmland from production to encouraging producers to adopt best management practices (BMPs) on working farmland (Cattaneo, 2003; Claassen, Cattaneo, and Johansson, 2008). Programs such as the Environmental Quality Incentives Program (EQIP) were introduced in the Federal Agriculture Improvement and Reform Act of 1996 to partially reimburse producers for voluntarily adopted BMPs on working farmland (Aillery, 2006). These programs were designed to maximize environmental benefits per dollar disbursed by targeting land where BMP adoption would provide the greatest environmental benefit without removing land from agricultural production (Claassen, Cattaneo, and Johansson, 2008; Reimer and Prokopy, 2014).

Producers who qualify to participate in the working farmland programs can select from a variety of BMPs to mitigate many different environmental concerns. Winter cover crops (EQIP Practice Code 340) and no-tillage planting (referred to as no-till hereafter) (EQIP Practice Code 329) are two BMPs heavily marketed by the Natural Resource Conservation Service (NRCS) to producers in the Southeast (US Department of Agriculture (USDA) NRCS, 2017). Winter cover crops are planted after the cash crop is harvested (typically fall) and terminated before the next cash crop is planted (typically spring). No-till planting limits disturbance the soil. Reducing water-based soil erosion is the primary purpose of both BMPs. Cover crops and no-till mitigate water-induced erosion by covering bare soil over the winter (i.e., non-growing period) (Snapp et al., 2005; Derpsch et al., 2010).

Studies find that adoption of BMPs increases with higher cost-share payments (Cooper, 1997; Cooper 2003; Lichtenberg, 2004; Lichtenberg and Smith-Ramirez, 2011). Cooper (1997) estimated producer adoption of various BMPs as cost-share payments change. He found that adoption increased for the BMPs analyzed as cost-share payments increased, but producers were more responsive to increases in cost-share payments for some BMPs than others. For example, producer responsiveness to a cost-share payment increase for conservation tillage was low, but producers were more responsive to increases in cost-share payments for soil moisture testing. Cooper (2003) extended Cooper (1997) by analyzing producer decisions to accept incentive payments in return for the adoption of BMPs bundles. Cooper (2003) found that increasing a cost-share payment for one BMP could increase the likelihood of a producer adopting a related BMP. Lichtenberg (2004) used survey data combined with information on installation costs of BMPs to estimate latent demand models for seven BMPs. As cost-share payment increased, adoption of all BMPs increased, exhibiting a standard downward-sloping demand curve.

Despite the availability of cost-share payments and possible production and soil fertility benefits, adoption of cover crops and no-till is limited in the US. Winter cover crop use remains low nationally, with only 3.2% of harvested land utilizing the BMP in 2012 (USDA National Agricultural Statistics Service (NASS), 2012). While more widely practiced than cover crops, no-till still has significant room to expand, with approximately 23% of total US crop land planted using no-till (USDA NASS, 2012). Adoption of cover crops and no-till varies largely by region and is higher in the Economic Research Service's regional classifications of the Southern Seaboard and Mississippi Portal regions than some other parts of the country (USDA NASS, 2015).

Several studies have found that producers are reluctant to adopt cover crops and no-till because they are unsure of their economic benefits (Snapp et al., 2005; Tripplett and Dick, 2008; Levidow et al., 2014; Schipanski et al., 2014). The hypothesized impacts of non-financial willingness to adopt (WTA) factors were the impetus behind several studies investigating producer risk perceptions and BMP adoption (Prokopy et al., 2008; Baumgart-Getz, Prokopy, and Floress, 2012; Tudor, 2014; Arbuckle and Roesch-McNally, 2015; Liu, Burns, and Heberling, 2018). Arbuckle and Roesch-McNally (2015) reported respondents associated cover crops with a variety of risk including decreased yields, crop insurance complications, and delayed planting and that producers who believed cover crops were associated with a higher level of production risk and increased planting difficulty were less likely to adopt the BMPs. However, Baumgart-Getz, Prokopy, and Floress (2012) concluded that producers' perceived risk of BMPs were diminishing over time with increasing knowledge on how to effectively implement these BMPs.

These studies are insightful for elucidating the impact of perceived risk on BMP adoption through the use of perceived risk using self-assessment questions or variables hypothesized to proxy risk. Furthermore, the studies that have attempted to measure producers' risk preferences used proxy or self-assessment variables for risk preferences. For example, Schoengold, Ding, and Headlee's (2014) analysis of the impacts of crop insurance programs on the use of conservation tillage assumed enrollment in crop insurance meant the producer was risk averse. They found enrollment in crop insurance programs did not impact the adoption of conservation tillage. Risk averse producers were found to be less likely to adopt Direct elicitation methods are an alternative, more systematic approach for measuring producer risk preferences than proxy variables or self-assessments (Holt and Laury, 2002; Brick, Visser, and Burns, 2012; Eckel and Grossman, 2002, 2008; Ihli, Chiputwa, and Musshoff, 2016). Prokopy et al. (2008) found that producer willingness to take risks is significant ($p < 0.05$) (in both directions) in the majority of WTA studies. While Prokopy et al.'s (2008) meta-analysis did not find risk preference to be a consistent driver of adoption, six of nineteen examined studies found producer willingness to take risk to be a positive predictor of BMP adoption.

This chapter determines the effect of producer risk preference and other factors such as cost-share payments on willingness to adopt (WTA) cover crops and no-till using a risk preference elicitation method to measure producer risk preferences. Data from a Tennessee row crop producer survey was used. The results provide a better understanding of producers' risk preferences and can guide future studies in measuring and assessing the risk preferences of producers.

Economic Framework

Adoption

A producer's WTA BMPs is frequently modeled using McFadden's (1974) random utility framework (e.g., Cooper, 1997, 2003; Cooper and Keim, 1996; Lichtenberg, 2004; and Lichtenberg and Smith-Ramirez, 2011). This model assumes producers receive benefits from adopting a BMP exceeding the cost of its adoption. The decision toadopt BMP q is discrete; the producer either adopts the BMP ($q = 1$) or does not adopt the BMP ($q = 0$).

The producer is assumed to maximize expected utility. Let $U(y + C, r)$ represent the producer's utility function, where y is the sum of the benefits and costs from adopting the BMP; C is the cost-share payment from adopting the BMP and participating in the cost-share program; and r is the producer's risk preference level. Note that $U'(\cdot) > 0$ and $U''(\cdot) < 0$ and $r = -U''(r)/U'(r)$. Depending on the producer's risk preference level, some producers are willing to exchange higher total benefits for lower variability in benefits. A producer would be willing to adopt the BMP when the expected utility of adoption exceeds the utility of not adopting, or when $U(q = 1, y + C, r\ ) \geq U(q = 0, y, r)$.

In practice, the producer's utility function is unknown because some components are unobserved. From the researcher's perspective, utility is observed as a systematic and random component. Thus, similarly to Jensen et al. (2015), the indirect utility function for a producer that is willing to adopt BMP m ($m = 1,\ldots, M$), given a cost-share payment encouraging adoption, is

(1) $V_m^1(q_m^* = 1, y_m + C_m, r; x) + \varepsilon_m^1 \geq V_m^0(q_m^* = 0, y_m, r; x) + \varepsilon_m^0,$

where V_m^1 is the indirect utility when a producer adopts BMP m; q_m^* is a latent variable indicating the propensity to adopt BMP q; V_m^0 is the indirect utility when producer does not adopt BMP m; ε_m^1 is the unobservable, independent, and identically distributed random error for producers that adopt the BMP; ε_m^0 is the unobservable, independent, and identically distributed random error for a producer that does not adopt the BMP; and x is a vector of other attributes and characteristics of the producer that may impact WTA. The likelihood a producer adopts the BMP is

(2) $\text{Prob}(WTA \leq C) = \text{Prob}(V_m^0 + \varepsilon_m^0 \leq V_m^1 + \varepsilon_m^1) = \text{Prob}(\varepsilon_m^0 - \varepsilon_m^1 \leq y_m + \alpha_m C).$

Producer preference for risk (r) and other individual or farm business attributes (x) could also influence BMP adoption at a given cost-share payment; for example

(3) $\text{Prob}(WTA \leq C) = F_{\varepsilon_m}(y_m + \alpha_m C + \lambda r + x_m' v_m),$

where λ and v_m are parameters to be estimated; and F_{ε_m} is the cumulative distribution function of the random error.

Risk

Risk preference elicitation methods are difficult to clearly apply in the context of agricultural producer decisions because crop yield and farm income are dependent on a complicated variety of largely exogenous factors (Menapace, Colson, Raffaelli, 2013; Ihli, Chiputwa, and Musshoff, 2016). Menapace, Colson, Raffaelli (2013) modified Eckel and Grossman's (2008) approach to measure Italian producer risk preferences. They examined the correlation between risk attitudes and producer belief that a crop value loss would occur due to a weather event. They found the more risk averse a producer is, the greater their perception of the probability of farm loss occurring. A producer's decision making under risk is determined not only by their attitude towards risk, but also by their belief regarding the likelihood of an uncertain outcome occurring.

Brick, Visser, and Burns (2012) surveyed fisherman in South Africa about their risk preferences. They presented fisherman with a paired lottery-choice where probabilities of high and low payoffs were varied while the payoffs were held constant. They found education and age impacted risk aversion. Ihli, Chiputwa, and Musshoff (2016) extended the literature by comparing the responses of Ugandan coffee producers to a Holt and Laury (2002) paired lottery-choice, which has constant payouts for each lottery but the probability of receiving the payout varied, with the experiment design from Brick, Visser, and Burns (2012). They analyzed how demographic and socioeconomic characteristics influenced risk preferences and found several demographic and socioeconomic characteristics affected producer risk preferences. Risk aversion decreased with years of education and increased with age.

This study uses a modified Eckel and Grossman (2008) lottery-choice experiment risk elicitation method for measuring producer risk preferences. The risk preference measure is then used to explain WTA conservation tillage and cover crops. The lottery-choice question was designed similarly to Menapace, Colson, Raffaelli (2013), whereby a producer is given a menu that includes consecutive choices between paired lotteries. Option one for each pair is a sure outcome of 100% of their expected farm net income. The second option in each pair is a 50-50 gamble where farm net income could be higher or lower than the sure outcome. The technologies offer higher potential increases and decreases to net farm income as the menue progresses. The number of times a producer selected the 50-50 outcome is converted to a constant relative risk aversion coefficient *r* assuming a power risk utility function $U(\pi) = (\pi^{1-r})/(1-r)$, where π is net farm income. The constant relative risk aversion coefficient (r^*) solves the equation

$$(4)\quad \frac{\pi^{1-r}}{1-r} = 0.5\frac{\eta\pi^{1-r}}{1-r} + 0.5\frac{\theta\pi^{1-r}}{1-r} = r^*,$$

where η is the potential decrease in π with the adoption of the BMP; $\theta$is the potential increase in π with the adoption of the BMP; and r^* is the elicited risk preferences level for each individual (Menapace, Colson, and Raffaelli, 2012). Excel solver was used to find the bounds of r, with midpoints of technologies A, B, C, D, and E's *r* bounds assigned based on the riskiest technology adopted by the respondent. Producers who did not adopt any technologies were assigned a value of *r* just above the bounds of technology A's *r* range, and those who adopted all technology F (the most risky technology) were assigned an *r* just below the bounds of technology E.

Data

Data were collected from a 2017 survey of row crop producers in West and Middle Tennessee. A mailing list of corn, cotton, soybean, and wheat producers was obtained from the USDA Farm Service Agency (FSA) using the Freedom of Information Act (FOIA). The mailing list included all producers and land owners in the region who received a payment from USDA FSA from 2012-2016. A map of survey distribution can be found in Figure 18.

Following Dillman's (2007) mail survey total design method recommendations, a postcard was first mailed on January 26, 2017 to inform row crop producers about the mail survey they would be receiving. Mail surveys were sent out on February 8, 2017. A prepaid postage envelope was included, as well as a cover letter explaining the purpose of the survey and an insert detailing the benefits and requirements of winter cover crops, no-till, and IWM. A reminder postcard was sent out on February 17, 2017, followed by a second round of questionnaires on March 8, 2017. This mailing also included a postage-paid return envelope and cover letter reiterating the purpose of the survey. The survey was initially mailed to 5,184 addresses, with declines to participate, undeliverable addresses, and replies that the recipient does not farm reducing the survey pool to 3,84l. A total of 344 responses to the mail survey were received, resulting in a 9% response rate.

The survey included 6 sections, with the first including questions about acreage owned and leased, yield, and production costs. The second, third, and fourth sections covered questions on no-till, cover crops, IWM; respectively. Each of these sections included a question that asked producers if they would adopt the BMP given a cost-share payment. Each practice had five independent cost-share payments that were uniformly distributed to respondents. Cover crop adoption costs were set at $77 per acre with cost-share payments of $15, $30, $45, $62, and $77 per acre. Adoption costs of no-till were set at $25 per acre. Cost-share payments for no-till were set at $5, $10, $15, $20, and $25 per acre. Since few respondents used irrigation, data on IWM adoption was limited. For this reason, this BMP was dropped from the analysis.

The fifth section of the survey included the risk preference elicitation question (Figure 19). The final section of the survey solicited information on producer demographics including age, education, and income.

Estimation

We estimate coefficients for a simultaneous bivariate probit for WTA cover crops ($q_{CC}^* = 1$ for cover crop adoption and $q_{CC}^* = 0$ for non-adopters) and no-till ($q_{NT}^* = 1$ for no-till adoption and $q_{NT}^* = 0$ for non-adopters) and tobit censored regression model that considers factors impacting the constant relative risk aversion coefficient using full information maximum-likelihood. A double-bounded tobit model was selected for the risk aversion equation to ensure predicted values for risk aversion were within the range of possible values. Similarly to Ihli, Chiputwa, and Musshoff (2016), the dependent variable is the mid-point of the constant relative risk aversion coefficient bounds found from equation (4). Producer risk preferences have been shown to be correlated with age and education (Brick, Visser, and Burns, 2012; Ihli, Chiputwa, and Musshoff, 2016), but do not appear to influence the adoption of BMPs (Cooper, 1997; Cooper 2003; Lichtenberg, 2004; Lichtenberg and Smith-Ramirez, 2011). Therefore, age and education are included in the risk aversion equation and exclude these from the WTA bivariate probit model. Since the risk aversion coefficient is an independent variable in the WTA model, information about the impact of age and education enters the WTA model through the risk aversion equation. However, the producer's purchase of crop insurance is included in the WTA and risk equations to assess how crop insurance enrollment is correlated with risk preferences and WTA.

The model is specified as

$$(5)\quad q^*_{CC,i} = \beta_0 + \beta_1 C_{cci} + \beta_2 r_i^* + \beta_3 corn_i + \beta_4 cotton_i + \beta_5 beans_i + \beta_6 csurvey_i + \beta_7 weeds_i + \beta_8 large_i + \beta_9 cropins_i + \varepsilon_{CC,i}\ ,$$

$$(6)\quad q^*_{NT,i} = \gamma_0 + \gamma_1 C_{NTi} + \gamma_2 r_i^* + \gamma_3 corn_i + \gamma_4 cotton_i + \gamma_5 beans_i + \gamma_6 csurvey_i + \gamma_7 beans_i + \gamma_8 large_i + \gamma_9 cropins_i + \varepsilon_{NT,i},$$

$$(7)\quad r_i^* = \omega_0 + \omega_1 edu_i + \omega_2 age_i + \omega_3 cropins_i + \varepsilon_{r,i},$$

where $C_{cc,i}$ is the cost-share payment offered for cover crop adoption for individual *i* (*i*=1,..,*N*); $C_{NT,i}$ is the cost-share payment offered for no-till adoption; r_i^* is the risk preference level measured from lottery game; $corn_i$ is an indicator variable that is one if corn makes up 50% or more of total 2016 acreage, otherwise zero; $cotton_i$ is an indicator variable that is one if cotton makes up 50% or more of total 2016 acreage, otherwise zero; $beans_i$ is an indicator variable that is one if soybeans make up 50% or more of total 2016 acreage, otherwise zero; $csurvey_i$ is one if the producer has confidence the survey will influence farm programs, negative one if the producer is does not believe the survey will influence farm programs, and zero if the producer is unsure the survey will influence farm programs; $weeds_i$ is an indicator variable that is one if the respondent has identified herbicide resistant weeds on his or her operation, otherwise zero; $large_i$ is equal to one if the total acres farmed in 2016 is greater than 1,000 acres, otherwise zero; $cropins_i$ is an indicator variable that is one if the producer had crop insurance in 2016; edu_i is a binary variable that is one if the producer has a college degree, zero otherwise; age_i is a continuous variable and is the age of the respondent; $\beta_0, \ldots, \beta_9, \gamma_0, \ldots, \gamma_9$, and $\omega_0, \ldots, \omega_3$, are parameters to be estimated; $\varepsilon_{CC,i}$ is the random error component for the cover crop adoption probit that is conditional on the independent variables with mean zero and a constant variance; $\varepsilon_{NT,i}$ is the random error component in the no-till probit model that is conditional on the independent variables with mean zero and a constant variance; and $\varepsilon_{r,i}$ is random error component that is conditional on the independent variables with mean zero and a constant variance. The error terms in equations 5-7 are assumed to follow a multivariate normal distribution with mean of zero, variance of one, and

$$(8)\quad \begin{bmatrix} \varepsilon_{CC,i} \\ \varepsilon_{NT,i} \\ \varepsilon_{r,i} \end{bmatrix} \sim MVN\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{\varepsilon_{CC},\varepsilon_{NT}} & \rho_{\varepsilon_{CC},\varepsilon_r}\sigma_{\varepsilon_r} \\ \rho_{\varepsilon_{CC},\varepsilon_{NT}} & 1 & \rho_{\varepsilon_{NT},\varepsilon_r}\sigma_{\varepsilon_r} \\ \rho_{\varepsilon_{CC},\varepsilon_r}\sigma_{\varepsilon_r} & \rho_{\varepsilon_{NT},\varepsilon_r}\sigma_{\varepsilon_r} & \sigma^2_{\varepsilon_r} \end{bmatrix} \right).$$

Assuming the error terms are correlated ($\rho \neq 0$) will indicate the relationship between unexplained factors across a producer's decision to adopt cover crops, adopt no-till, and risk aversion. We test also if the constant relative risk aversion coefficient is endogenous to the adoption of cover crops and no-till using a Wald test (Greene, 2011). The null hypothesis is that endogeneity will not be present (Greene, 2011). Additionally, a likelihood ratio test for over-identification was performed, with a null hypothesis that variances are constant for all independent variables, and thus the instruments are valid (Greene, 2011). If the error terms are not correlated and the risk aversion coefficient is not endogenous, the model will be reduced to separate probits for the WTA cover crops and no-till and a separate tobit model for risk aversion (Greene, 2011).

The coefficients of a bivariate probit or tobit model do not directly represent the marginal change in the probability of participation or risk aversion (Greene, 2011). However, the sign of the estimated coefficients indicate the directional impact of the explanatory variable on BMP adoption and risk preferences. Marginal effects were not estimated for the tobit model because incremental changes in independent variables impact on a producer's constant relative risk aversion coefficient are not that informative. For example, moving from an estimated constant relative risk aversion value of three to two indicates the producer becomes more risk tolerant, but it is unclear how to interpret the relative magnitude of this change. Thus, results are discussed in terms of directional impact of explanatory variable on risk preferences. Marginal effects were calculated for the bivariate probit following Greene (2011). The model was estimated using the PROC QLIM procedure in SAS (SAS Institute, 2009).

Variable Hypotheses

Descriptions and expected signs of the independent variables are provided in Table 8. Coefficients for the cost-share payments (C_{CC} and C_{NT}) are expected to be positive since studies consistently conclude that in increase in cost-share payments increase BMP adoption (Cooper, 1997; Cooper and Keim, 1996; Prokopy et al., 2008; Baumgart-Getz, Prokopy, and Floress, 2012). Economic intuition based on the producer's utility function also suggests that an increase in cost-share amount will indicate it is more likely the benefits from adoption will outweigh the costs.

The variables *corn*, *cotton*, and *beans* were created to identify the majority of the crop farmed in 2016 by a producer. We hypothesized the coefficients for corn (*corn*) and soybean (*beans*) could be either positive or negative. Cotton production, on the other hand, results in low amounts of soil surface crop residue post-harvest, which can increase soil erosion (Nyakatawa et al., 2001; Osteen et al., 2012). Cotton production is also common in areas with sandy or silty soils, which are more susceptible to soil erosion (Bradley and Tyler, 1996; Boquet et al., 2004). Therefore, we hypothesized the coefficients for cotton (*cotton*) to be positive since more cotton acres might result in an increase in the likelihood of adopting soil conservation practices.

Meta-analysis of adoption studies suggests that the attitude of a producer can play a large role in his or her decision to adopt (Baumgart-Getz, Prokopy, and Floress, 2012). Several studies have explored the impact of consequentiality, which is defined as a producer's belief that the survey will impact future programming (Li et al., 2016; Carson and Groves, 2007). As a measure of producer attitude, a variable indicating if the respondent was confident the survey would influence farm programs was included. We were uncertain how *csurvey* would impact producer risk preference. *Weeds* was included to consider if producers who had identified herbicide resistant weeds on their farm were more likely to adopt BMPs that could potentially aid in weed control. We hypothesized that the coefficients for *weeds* could either be positive or negative, based on the BMP being adopted – positive for cover crop (suppression of weed growth during the winter and early spring, thus reducing the weed seed bank) and negative for no-till (mechanical weed control may be required to control herbicide resistant weeds). It was also hypothesized that the coefficients for *large* could be either positive or negative, since previous studies have been inconclusive on the impact of size of WTA (Baumgart-Getz, Prokopy, and Floress, 2012; Prokopy et al., 2008).

Arbuckle and Roesch-McNally (2015) indicated that producers who believed cover crops were associated with a higher level of risk were less likely to use the BMPs. It was therefore hypothesized that the risk coefficient (*r*) derived from the lottery-game question would be negative in both adoption models. This means that a more risk averse producer would be less likely to adopt the respective BMP. Finally, it was hypothesized that producers who had crop insurance in 2016 *(cropins)* would be more likely to adopt a BMP.

Risk tolerances were assumed to increase as the producer gets older (*age*). We hypothesized that an increase in education (*edu*) would increase a producer's risk tolerance. The hypothesized signs for age and education align with previous research (Brick, Visser, and Burns, 2012; Ihli, Chiputwa, and Musshoff, 2016). Finally, it was hypothesized that producers who had crop insurance in 2016 *(cropins)* would be more risk averse than producers who were not enrolled in crop insurance (Schoengold, Ding, and Headlee, 2014).

Results

Summary statistics

Table 9 shows the bounded risk aversion coefficients from the lottery-choice question and the percentage of producers willing to participate in each lottery. A lower risk aversion coefficient indicates greater risk tolerance, and conversely, producers with higher risk aversion coefficients are more risk averse. A little over half the respondents indicated they would adopt technology A. However, this percentage decreased as the potential losses associated with each technology increased, with approximately a fifth of the respondents indicating they would adopt technology

F. This finding is similar to previous studies (Brick, Visser, and Burns, 2012; Menapace, Colson, and Raffaelli, 2013; Ihli, Chiputwa, and Musshoff, 2016).

The percentage of producers willing to adopt cover crops at a $15 per acre cost-share payment was approximately 40% (Figure 20). This percentage dropped slightly to 37.5% when the cost-share increased to $30 per acre (Figure 20). However, WTA cover crops increased when cost-share increased from $30 per acre to $77 per acre (Figure 20). At a 100% cost-share payment of $77 per acre, 91% of the survey respondents were willing to adopt (Figure 20). For no-till, a majority of respondents (64%) indicated they would adopt when a $5 per acre cost-share payment was offered (Figure 21). WTA no-till increased as the cost-share payment increased with about 89% of the respondents saying they would adopt no-till for a 100% cost-share payment (Figure 21).

The average cover crop cost-share payment (C_{CC}) offered was $45 per acre, and the average no-till cost-share payment (C_{NT}) offered to producers in the survey averaged $15 per acre (Table 10), which is the median cost-share payment provided in the survey. The average constant relative risk aversion coefficient was 3.33 (Table 10). Few producers indicated that most of their 2016 acres were in corn (*corn*) and cotton (*cotton*), but approximately 42% stated that over half of their 2016 acres were in soybean (*beans*) (Table 10). Most respondents indicated they were unsure that the survey would influence farm programs (*csurvey*). About 70% of the respondents said they have herbicide resistant weeds on their farm and approximately 60% of the respondents purchased crop insurance in 2016 (*cropins*). Only 22% of the respondents farmed over 1,000 acres in 2016 (*large*), and the average farm size was 710 acres. While few had farms over 1,000 acres in 2016, the average farm size of respondents is considerably larger than the state average of 162 acres per operation (USDA NASS, 2016). Under half, (41%), of the respondents had at least a four-year college degree (*edu*), and the average age (*age*) of producers was approximately 64 (Table 10).

Correlation coefficients and tests

The correlation coefficients of the residuals were not significant for any combination of the model (Table 11). This means the unexplained factors in risk, WTA cover crops, and WTA no-till were not correlated. Furthermore, we fail to reject the null of the Wald test that the constant relative risk aversion coefficient was not endogenous with cover crops and no-till. We failed to reject the null of the likelihood ratio test for over-identification that the instruments are valid for both the cover crop and no-till model. Results from these tests indicate the instruments are valid but risk is not endogenous with cover crops and no-till. Therefore, parameter estimates are presented for three separate models: 1) a probit model for WTA cover crops, 2) a probit model for WTA no-till, and 3) tobit model for risk preferences.

WTA models

The cost-share payment coefficient was positive and significant for cover crop adoption ($p < 0.01$). This indicates a one dollar per acre increase in the cost-share payment would increase the likelihood of a producer being willing to adopt cover crops by 0.78% (Table 12) or for every $10 per acre increase in the cost-share payment, the probability of cover crop adoption increases 7.8%. These results are similar to what previous studies have observed (Cooper, 1997; Cooper 2003; Lichtenberg, 2004; Lichtenberg and Smith-Ramirez, 2011).

The coefficient sign for the constant relative risk aversion coefficient was negative and significant ($p < 0.05$) for cover crop adoption (Table 12). Thus, an increase in the constant relative risk aversion coefficient decreased WTA cover crops. Since the relative magnitude of the risk aversion coefficient is not directly interpretable, marginal effects were not estimated and directional effects are discussed. These results align with the conclusions of Menapace, Colson, Raffaelli (2013), which concluded that more risk averse producers tend to perceive greater possibilities of farm loss. Therefore, it is likely that more risk averse producers would be more skeptical of BMP benefits, and thus less likely to adopt

Whether corn, cotton, or soybean acreage makes up more than 50% of the operation was not found to influence WTA cover crops. Having confidence in the survey's ability to impact farm programs was significant ($p < 0.05$) and positive, with producers who believed the survey would be consequential being 14.44% more willing to adopt cover crops than those who did not. Identification of herbicide resistant weeds was not found to have no influence on producer WTA cover crops.

The cost-share coefficient was insignificant in WTA no-till, meaning producers were not responsive to cost-share payment increases for this BMP (Table 12). Cooper (1997) found producers were more responsive to increases in cost-share payments for some BMPs than others. A large percentage of Tennessee producers already use no-till, which suggests that no-till is a more profitable practice than conventional tillage without a cost-share payment.

Similar to WTA cover crops, the coefficient sign for the constant relative risk aversion coefficient was significant ($p < 0.01$) and negative for WTA no-till. Thus, an increase in the risk aversion coefficient decreased WTA no-till. These findings are in line with six of 19 examined studies included in Prokopy et al.'s (2008) meta-analysis.

As was also the case with cover crop adoption, having corn, cotton, or soybean acreage make up more than 50% of the operation was not found to impact adoption of no-till. A belief that the survey would be consequential increased the likelihood a producer would adopt no-till by 8.96% ($p < 0.1$). If a producer purchased crop insurance in 2016, they were 14% more likely to adopt no-till. Crop insurance enrollment is not typically included in WTA models, and it does not appear in meta-analysis on the subject (Baumgart-Getz, Prokopy, and Floress, 2012). However, this study extends the literature by investigating the potential role crop insurance enrollment plays in cover crop and no-till adoption.

Overall, results show that risk preference does impact the likelihood of a producer adopting cover crops and no-till. One possible policy alternative to encourage the use of BMPs while mitigating producer risk aversion level, might be coupling BMP cost-share payments with crop insurance subsidies. This policy could possibly increase crop insurance subsides if a BMP is adopted. This would provide risk averse producers with protection while encouraging the use of crop insurance and the adoption of BMP. Boyer et al. (2017) recently found in a small sample study of Tennessee and Mississippi producers that they would be interested in participating in programs that coupled the use of crop insurance and BMPs.

Risk aversion

Coefficients and significance levels of independent variables in the model can be found in Table 11. A college education increased producer risk tolerance ($p < 0.05$). The results for education match the previous literature and the expected sign (Brick, Visser, and Burns, 2012; Ihli, Chiputwa, and Musshoff, 2016) and suggest that the more educated producers are more willing to accept risk. The coefficient for age was positive ($p < 0.01$). This indicates that as producers increase in age, they become more risk averse. It was also found that being enrolled in crop insurance did not have a significant impact on producer risk preference. That is, crop insurance might not be a suitable proxy for producer risk preferences.

Conclusions

Regardless of the cost-share payments and environmental benefits from adopting of cover crops and no-till, the use of these BMPs is small in the US. Research has suggested that producers are reluctant to implement these BMPs due to their uncertain economic benefits (Snapp et al., 2005; Tripplett and Dick, 2008; Levidow et al., 2014; Schipanski et al., 2014). Most of these studies, however, have investigated how producer perceptions of BMP risk impacts adoption and do not measure producer risk preference. Therefore, the objective of this research is to determine the impact of producers' risk preference and other factors such as cost-share payments on WTA cover crops and no-till using a risk preference elicitation method to measure producers risk preferences.

Data from Tennessee row crop producer survey was used. Probits were implemented to model WTA cover crops and no-till, and a double bounded tobit was used to model the constant relative risk aversion coefficient. This study extends the literature by showing how risk preference impacts the adoption of BMPs and could be insightful to inform policy revisions to consider the impact of risk on BMP adoption.

If a producer believes the survey will impact policy, they have a higher likelihood of adopting cover crops and no-till. The cost-share payment coefficients was significant in cover crop adoption ($p < 0.01$) and insignificant in no-till adoption. Thus, more producers would plant cover crops if the cost-share payment increased; however, no-till planting will be used without a cost-share payment. Cover crop adoption is not correlated with producer risk preference, but a risk averse producer would be less likely to adopt no-till. Younger, college educated producers had a comparatively higher risk tolerance than older producers and those without a four-year degree. Based on these findings, policy makers might consider reallocating cost-share funding for no-till to other BMPs that are responsive to cost-share payments.

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Appendix G Tables and Figures

Table 8. Definition and Predicted Signs for the Independent Variables

Variable	Description	Predicted Sign
Adoption Regressions		
C_{CC}	Cost-share payment assigned for adoption cover crops per acre	+
C_{NT}	Cost-share payment assigned for adoption of no-till per acre	+
r	Latent risk coefficient	-
corn	=1 if corn makes up 50% or more of total 2016 acreage; otherwise zero	+/-
cotton	= 1 if cotton makes up 50% or more of total 2016 acreage; otherwise zero	+
beans	= 1 if soybeans makes up 50% or more of total 2016 acreage; otherwise zero	+/-
csurvey	Are you confident this survey will influence policy? Yes = 1, No = -1, and Unsure = 0	+/-
weeds	Have you identified herbicide resistant weeds on your farm? Yes =1, No = 0	+/-
large	Total acres farmed in 2016 is greater than1,000 acres	+/-
cropins	Were you enrolled in crop insurance in 2016? Yes = 1, No = 0	+
Risk Censored Regression		
edu	= 1 when if the producer has a college education; otherwise zero	-
age	Age of primary operator in years	+
cropins	Were you enrolled in crop insurance in 2016? Yes = 1, No = 0	+

Table 9. Latent Constant Relative Risk Aversion Coefficients

Technology	Constant Relative Risk Aversion Coefficient (*r*) Bound	Percentage of Farmers Adopting Technology	Assigned *r*	N
Not Adopt	$r > 6.889$	-	6.889	55
A	$2.489 < r < 6.889$	53.70%	4.689	14
B	$1.672 < r < 2.489$	49.75%	2.081	31
C	$1.256 < r < 1.672$	35.47%	1.464	25
D	$1.000 < r < 1.256$	24.63%	1.128	10
E	$0.823 < r < 1.000$	22.17%	0.912	4
F	$0.823 < r$	20.20%	0.823	37

Table 10. Summary Statistics of Independent Variables (N = 344)

Variable	Mean	Standard Deviation	Minimum	Maximum
Adoption Regressions				
C_{CC}	45.12	22.275	5	25
C_{NT}	14.93	6.860	15	77
r	3.36	2.576	0.823	6.889
corn	0.12		0	1
cotton	0.07		0	1
beans	0.42		0	1
csurvey	-0.11	0.681	-1	1
weeds	0.69		0	1
large	0.23		0	1
cropins	0.58		0	1
Risk Censored Regression				
edu	0.40		0	1
age	63.56	14.180	21	98
cropins	0.58		0	1

Table 11. Correlation Coefficients of Residuals from Simultaneous Bivariate Probit and Tobit Model

Dependent Variables	Model Fit Statistics	No-Till Adoption	Risk Aversion
Cover Crop Adoption		0.127	0.034
No-Till Adoption		-	0.369
P-Value for Wald Test for Endogeneity	0.943	0.231	-
P-Value Likelihood Ratio Test for Over Identification	0.385	0.796	-

Note: Double asterisks represent p-values less than 0.05.

Table 12. Parameter Estimates and Significant Marginal Effects for the Probit Models and Tobit Model (N = 344)

	Cover Crop Adoption Probit		No-Till Adoption Probit		Risk Aversion Tobit
Parameters	Parameter Estimates	Marginal Effects	Parameter Estimates	Marginal Effects	Parameter Estimates
Intercept $(\omega_0, \beta_0, \gamma_0)$	-0.709	-	0.917	-	3.802
C_{CC} (β_1)	0.027***	0.0078***	-	-	-
C_{NT} (γ_1)	-	-	0.004		-
r (β_2, γ_2)	-0.121**	-[a]	-0.137**	-[a]	-
corn (β_3, γ_3)	0.219	-	0.240	-	
cotton (β_4, γ_4)	-0.723	-	-0.958	-	-
beans (β_5, γ_5)	0.092	-	0.206	-	-
csurvey (β_6, γ_6)	0.516**	0.1444**	0.394*	0.0896*	-
weeds (β_7, γ_7)	0.129	-	-0.212	-	-
acre (β_8, γ_8)	0.0001	-	-0.0003	-	-
cropins $(\beta_9, \gamma_9, \omega_3)$	0.036	-	0.500*	0.141*	-0.385
edu (ω_1)	-0.654		-0.654		-0.857**
age (ω_2)	0.043		0.043		0.061***
McFadden R^2	0.254		0.189		0.790
Likelihood Ratio	46.322***		20.556**		-

Note: Single, double, and triple asterisks represents p-values less than 0.1, 0.05, and 0.01, respectively.

[a] Marginal effects for the risk aversion coefficient were not estimated because the relative magnitude of the change is not interpretable.

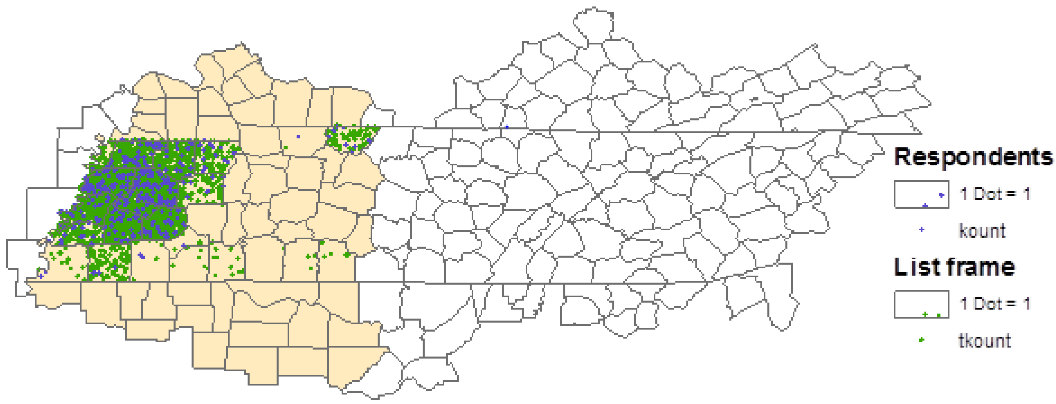

Figure 18. Map of Middle and West Tennessee Row Crop Survey Distribution

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

	---------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:		
Farm Technology	*DECREASING* your farm income by:		*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*	☐	☐

Figure 19. Lottery Choice Question Used to Elicit Producer Risk Preferences

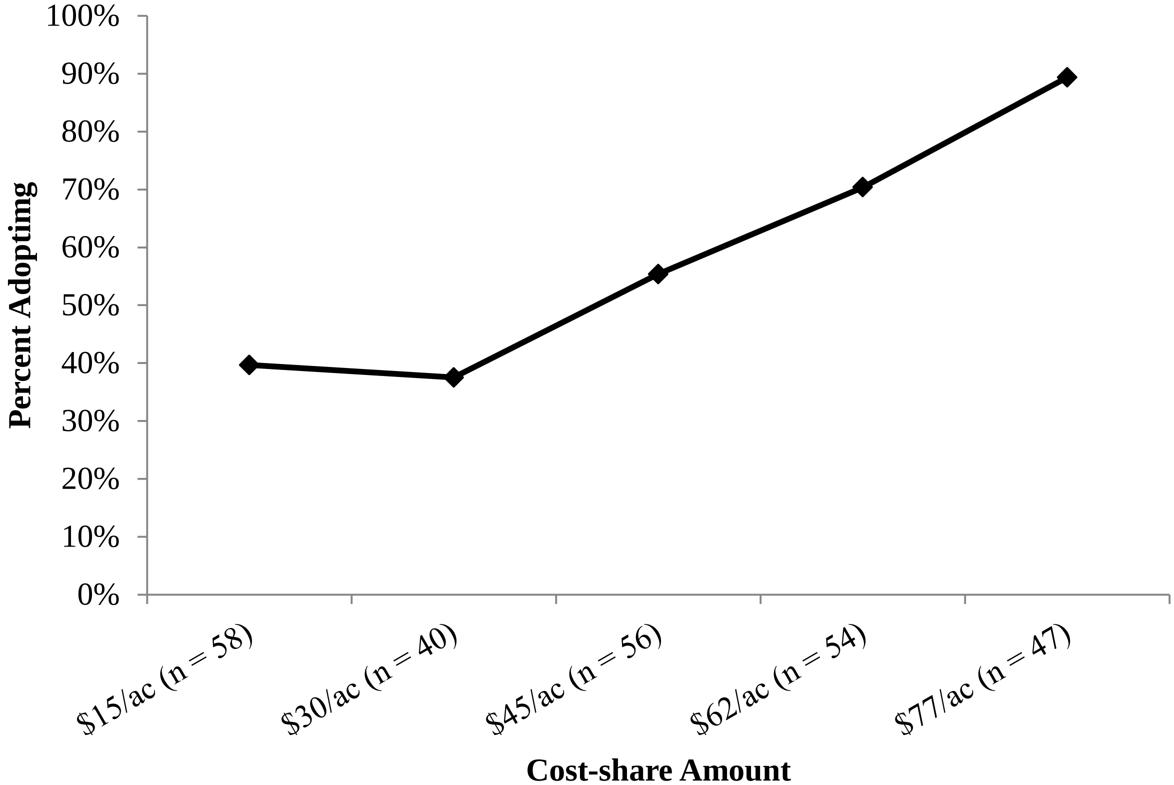

Figure 20. Percentage of Respondents Adopting Cover Crops at a given Cost-Share Payment

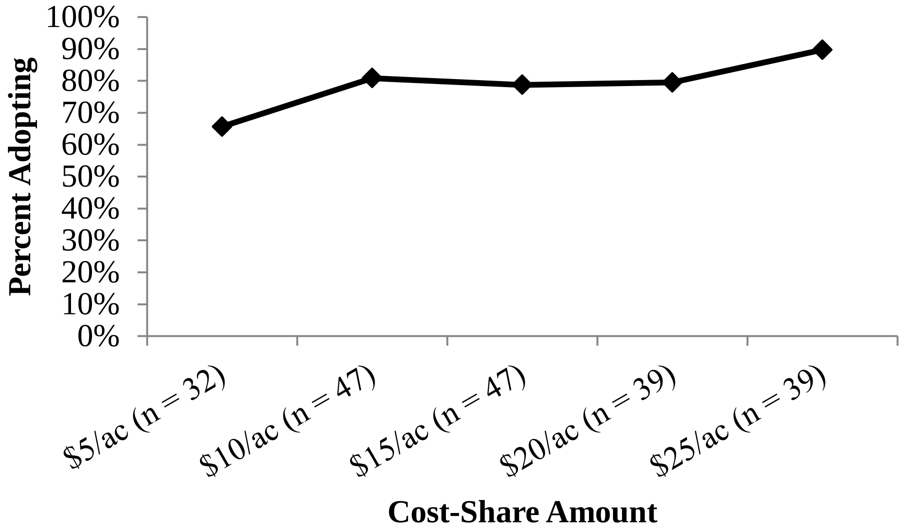

Figure 21. Percentage of Respondents Adopting No-Till at a given Cost-Share Payment

CONCLUSION

In order to encourage adoption of practices that aim to mitigate growing concerns regarding the availability of clean, fresh water, the federal government continues to promote the adoption of a variety of BMPs by offering cost-share payments that partially reimburse qualifying producers for the costs of adoption. Despite these efforts, BMP adoption rates remain low. A better understanding of how producer and farm characteristics impact BMP adoption could facilitate increases in efficiency in programmatic design and spending. Furthermore, knowledge of producer perceptions regarding the benefits of BMP adoption could offer insights into the effectiveness of BMP educational materials. Increased awareness of BMP producer benefits and availability of USDA cost-share payments may allow for the expansion of BMP adoption, improving regional soil and water quality.

This thesis presented two studies that focused on BMP adoption by row crop producers in Middle and West Tennessee. The objective of the first study was to present results from a 2017 survey of Middle and West Tennessee row crop producers. Survey topics included producer perceptions regarding the benefits and costs associated with no-till, cover crops, and IWM. Respondent responsiveness to BMP cost-share payments, and producer demographic information such as household income and age were also queried. The majority of survey respondents (87%) planted with no-till in 2016, while only 29% of respondents planted with cover crops. Common reasons producers cited for not growing cover crops included that the BMP was too expensive and increased planting difficulty. The most common barriers to IWM reported by respondents were installation expense, field size, and field shape. No-till and cover crops' abilities to improve soil quality/health, reduce erosion, and improve water quality were widely believed by survey respondents. However, they were less sure about the likelihood of the BMPs to increase yields and reduce yield variability. Data gathered from this survey will help us further understand how to design effective conservation policies and to get a better understanding of Tennessee producers' use of these BMPs.

The objective of the second study was to determine the effect of producer risk preference and other factors such as cost-share payments on WTA cover crops and no-till using a risk preference elicitation method to measure producer risk preferences. Findings indicate that if a producer believes the survey will impact policy, they have a higher likelihood of adopting cover crops and no-till. Also, more producers would plant cover crops if the cost-share payment increased; however, no-till planting will be used without a cost-share payment. Cover crop adoption is not correlated with producer risk preference, but a risk averse producer would be less likely to adopt no-till. Younger, college educated producers had a comparatively higher risk tolerance than older producers and those without a four-year degree. The results provide a better understanding of producers' risk preferences and will guide future studies in measuring and assessing risk preferences of producers.

VITA

After graduating from Seymour High School in Seymour, Tennessee in 2012, Kelsey M. Campbell began her undergraduate studies at the University of Tennessee, Knoxville. Kelsey completed her Bachelor of Science degree in Natural Resource and Environmental Economics with minors in Geography, Sustainability, and Watersheds in May 2016. She accepted a graduate research assistantship at the University of Tennessee, Knoxville with the Department of Agricultural and Resource Economics. She received her Master of Science degree in Agricultural and Resource Economics with a concentration in Natural Resource Economics and minor in Statistics in May 2018.