

ESSAYS ON THE ADOPTION AND INTENSIFICATION OF CONSERVATION
AGRICULTURAL PRACTICES UNDER RISK

by

DOMINGA ELIZABETH CANALES MEDINA

B.S., Pan-American Agricultural School, El Zamorano, 2006
M.S., Kansas State University, 2010

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2016

Abstract

In recent years, great attention has been placed on conservation systems for agricultural production. Conservation practices offer economic and environmental benefits, yet conventional practices remain the prevailing system in some regions. As conservation efforts are launched by different local and federal agencies, understanding farmers' motivations when adopting conservation practices is important to ensure the continuation of adoption through the development of programs that are tailored to meet farmers' preferences and constraints.

The purpose of the first essay was to identify the factors affecting farmers' choice of tillage practice at the crop level. Farmer's choice of No-till, Strip-till and Conventional tillage was modeled for dryland corn, wheat and soybean production in Kansas. The results show that tillage decisions are crop-specific and that factors such as risk aversion, baling and grazing of crop residue, crop acreage, and farmers' approach to adopting new technologies are significant factors affecting farmers' decisions.

The second essay focused on the adoption of continuous no-till, conservation crop rotation, cover crops, and variable rate application of inputs and the effect that incentive payments, payment mechanism, and off-farm environmental benefits from conservation have on the decision to adopt. This essay also examined the risk associated with the variability of net returns and its effect on farmers' willingness to adopt using a non-linear extended expected utility framework, allowing for the estimation of a utility parameter for net returns, farmer's subjective judgment of probabilities, and farmers' risk attitudes. Farmers were found to exhibit risk aversion, with an estimated risk premium of approximately 3% of net returns. Results also suggested a preference for federally-run programs and for programs with higher off-farm environmental benefits.

The third essay examined the timing of adoption of continuous no-till, cover crops, and variable rate application of inputs. This study found that risk aversion delays the timing of adoption of cover crops and variable rate application of inputs. However, the timing of adoption of continuous no-till was not affected by risk aversion. Findings also indicated that farmers who consider themselves innovators adopt at a faster rate than their counterparts.

ESSAYS ON THE ADOPTION AND INTENSIFICATION OF CONSERVATION
AGRICULTURAL PRACTICES UNDER RISK

by

DOMINGA ELIZABETH CANALES MEDINA

B.S., Pan-American Agricultural School, El Zamorano, 2006
M.S., Kansas State University, 2010

A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2016

Approved by:

Major Professor
Jason S. Bergtold

Abstract

In recent years, great attention has been placed on conservation systems for agricultural production. Conservation practices offers economic and environmental benefits, yet conventional practices remain the prevailing system in some regions. As conservation efforts are launched by different local and federal agencies, understanding farmers' motivations when adopting conservation practices is important to ensure the continuation of adoption through the development of programs that are tailored to meet farmers' preferences and constraints.

The purpose of the first essay was to identify the factors affecting farmers' choice of tillage practice at the crop level. Farmer's choice of No-till, Strip-till and Conventional tillage was modeled for dryland corn, wheat and soybean production in Kansas. The results show that tillage decisions are crop-specific and that factors such as risk aversion, baling and grazing of crop residue, crop acreage, and farmers' approach to adopting new technologies are significant factors affecting farmers' decision.

The second essay focused on the adoption of continuous no-till, conservation crop rotation, cover crops, and variable rate application of inputs and the effect that incentive payments, payment mechanism, and off-farm environmental benefits from conservation have on the decision to adopt. This essay also examined the risk associated with the variability of net returns and its effect on farmers' willingness to adopt using a non-linear extended expected utility framework, allowing for the estimation of a utility parameter for net returns, farmer's subjective judgment of probabilities, and farmers' risk attitudes. Farmers were found to exhibit risk aversion, with an estimated risk premium of approximately 3% of net returns. Results also suggested a preference for federally-run programs and for programs with higher off-farm environmental benefits.

The third essay examined the timing of adoption of continuous no-till, cover crops, and variable rate application of inputs. This study found that risk aversion delays the timing of adoption of cover crops and variable rate application of inputs. However, the timing of adoption of continuous no-till was not affected by risk aversion. Findings also indicated that farmers who consider themselves innovators adopt at a faster rate than their counterparts.

Table of Contents

List of Figures	xi
List of Tables	xii
Acknowledgement	xiii
Dedication	xvi
Chapter 1 - Introduction.....	1
1.1 Research Objectives.....	4
1.1.1 First Essay: Modeling the choice of tillage used for dryland corn, wheat and soybean production by farmers in Kansas	5
1.1.2 Second Essay: Adoption of in-field conservation practices under risk	6
1.1.3 Third Essay: Modeling the factors affecting farmers' timing of adoption of in-field conservation cropping practices.....	7
References	10
Chapter 2 - Modeling the choice of tillage used for dryland corn, wheat and soybean production by farmers in Kansas.....	12
2.1 Introduction.....	12
2.2 Objective	15
2.3 Literature Review	15
2.4 Data and methods.....	19
2.4.1 Model	19
2.4.2 Survey and Data Description	20
2.4.3 Explanatory Variables used in the Analysis	25
2.5 Results.....	29
2.6 Conclusions.....	40
References	43
Chapter 3 - Adoption of in-field conservation practices under risk.....	50
3.1 Introduction.....	50
3.2 Objective	51
3.3 Background Information.....	52

3.3.1 Conservation practice background information	52
3.3.1.1 Continuous no-till	53
3.3.1.2 Conservation crop rotation.....	54
3.3.1.3 Cover crops	56
3.3.1.4 VRA of inputs	57
3.3.2 Payment mechanisms and conservation programs	58
3.4 Literature Review	64
3.4.1 Conservation practices adoption	64
3.4.2 Risk in the adoption literature.....	68
3.4.3 Uncertainty and risk attitudes in stated preference methods.....	70
3.4.4 Summary	75
3.5 Methods	76
3.5.1 Random utility framework.....	76
3.5.2 Choice under uncertainty and risk preferences	77
3.5.2.1 Expected utility	78
3.5.2.2 Prospect theory.....	79
3.5.2.3 Incorporating risk in the random utility framework	81
3.5.3 Model estimation	82
3.5.3.1 Mean-standard deviation approach.....	83
3.5.3.2 Attribute specific extended expected utility	86
3.5.3.3 Error component model specification.....	87
3.5.3.3.1 Risk premium.....	88
3.5.3.3.2 Model assessment	90
3.6 Survey Design and Data	91
3.6.1 Survey methods.....	91
3.6.2 Survey data.....	94
3.6.3 Stated choice design.....	102
3.7 Results.....	111
3.7.1 Model results.....	111
3.7.1.1 Mean-variance approach.....	111

3.7.1.2 Attribute specific extended expected utility	113
3.7.1.2.1 Model fit	113
3.7.1.2.2 Contract attributes.....	117
3.7.1.2.3 Probability weights, risk attitude, and risk premium	122
3.7.2 Marginal Willingness to Accept	133
3.7.2.1 mWTA for conservation practices	133
3.7.2.2 mWTA for other contract attributes.....	137
3.8 Conclusion	138
3.9 Limitations and future research	141
References.....	143
Appendix A - Stated choice contract instructions.....	157
Appendix B - Mean-standard deviation approach estimated with a random parameters logit ...	160
Chapter 4 - Modeling the factors affecting farmers' timing of adoption of in-field conservation cropping practices	163
4.1 Introduction.....	163
4.1 Objective	165
4.2 Literature review	166
4.2.1 Conservation practice adoption.....	166
4.2.2 Duration analysis and technology adoption	169
4.3 Methods and data	171
4.3.1 Conceptual framework.....	171
4.3.2 Empirical model	174
4.3.3 Survey method	176
4.3.4 Survey data.....	177
4.3.5 Model estimation	180
4.3.5.1 Maximum likelihood estimation	182
4.3.5.2 Explanatory variables used in the analysis	184
4.4 Results and Discussions.....	191
4.5 Conclusions.....	198
4.6 Limitations and future research	199

References.....	200
-----------------	-----

List of Figures

Figure 3.1 Chicago Climate Exchange, historical price and volume traded.....	61
Figure 3.2 Kansas Farm Management Association membership by county.....	93
Figure 3.3 Percentage of farmers who currently used the selected conservation practices.	97
Figure 3.4 Percentage of farmers who currently use or have used the selected conservation practices for select cash crop.	98
Figure 3.5 Percentage of crop land under each practice	101
Figure 3.6 Distribution of the probabilities of net returns change in stated choice design.....	106
Figure 3.7 Example of choice task.....	109
Figure 3.8 Probability of adoption for each practice under varying incentive payments	121
Figure 3.9 Probability weighing functions.....	123
Figure 3.10 Distribution of predicted risk attitude parameters	126
Figure 3.11 Benefits from conservation practices selected by farmers as the three most important factors.....	128
Figure 4.1 Kaplan Meier survival estimates	193

List of Tables

Table 2.1	Adoption percentage of tillage practices by crop in Kansas	24
Table 2.2	Definition of variables and summary statistics	27
Table 2.3	Parameter estimates for the choice of tillage system in dryland corn, soybean and wheat	31
Table 2.4	Marginal effects for the choice of tillage system in dryland corn, soybean and wheat	33
Table 3.1	Average farm characteristics	96
Table 3.2	Farmer receiving incentive payments for practices used	100
Table 3.3	Contract attributes and attribute's levels	107
Table 3.4	Data summary statistics	110
Table 3.5	Model estimates for the mean-variance model	112
Table 3.6	Model estimate results for the attribute specific extended expected utility models ..	114
Table 3.7	Ben-Akiva and Swait test results	116
Table 3.8	Risk premium estimates	132
Table 3.9	Farmers' marginal willingness to accept (\$/acre)	135
Table 4.1	Average farm characteristics	179
Table 4.2	Descriptive statistics of Dependent and Explanatory Variables	186
Table 4.3	Accelerated Failure Time estimates	196

Acknowledgement

I would like to begin my acknowledgements by thanking some of those at Kansas State University who have been a source of great challenge and encouragement to me as I have worked through the doctoral process and culminating in this dissertation. I first want to thank my major professor, Dr. Jason Bergtold, for his help, friendship, guidance, wisdom and example. You were always so good in offering words of encouragement in the times when I needed it. Next, I would like to thank my committee members Dr. Jeffery Williams, Dr. Jeffrey Peterson and Dr. Marcellus Caldas for your guiding thoughts and words and the role they have played in shaping this dissertation. I would also like to thank other professors in the Department of Agricultural Economics who have also helped advance my thinking and have pushed me to higher levels of success. Specifically, I want to thank Dr. Vincent Amanor-Boadu, Dr. Mike Boland, Dr. Aleksan Shanoyan, Dr. Rich Llewelyn and Dr. Sean Fox. I would also like to extend my gratitude to others in the Department of Agricultural Economics who assisted in making things easier for me by performing in their roles with such excellence and by providing their friendship. Thank you to Deana Foster, Amanda Erichsen, Judy Maberry, Seleise Barret, and Mary Huninghake for always being helpful and for your friendship.

I would also like to acknowledge the following grants for funding the research that is now a part of this work: USDA, NIFA AFRI Foundational Grant #KS601924, “Small and Medium Size Farmers’ Ability and Willingness to Supply Carbon Offsets through Carbon Markets and Conservation Crop Production”; NSF, NSF BCS – 1227451, “Collaborative Research: Land Change in the Cerrado: Ethanol and Sugar Cane Expansion at the Farm and Industry Scale.”; NSF, CNH Grant 1313815, “CNH: Coupled Climate, Cultivation and Culture

in the Great Plains: Understanding Water Supply and Water Quality in a Fragile Landscape; and the South Central Sun Grant Initiative and Department of Transportation Grant # DTOS59-07-G-00053. I would like to thank all of the farmers that participated in the survey process for this dissertation and were so willing to share information on their operations. Also, a large measure of appreciation goes out to all of the extension agents for their partnership in hosting, recruiting and facilitating many of the data collection sessions that were fundamental to this process. Much gratitude goes out to the Kansas Farm Management Association (KFMA) and the farmers connected to this wonderful organization for also being a useful resource for this dissertation.

On a more personal level, I want to thank those in Kansas who made it such a wonderful home for me for these last few years. I want to thank Jane Fox, Jim Morrill, Courtney Mooney, Sara Nickoley, Melissa Rupp, and Matt Gleaves. I want to thank those colleagues that I have also shared some good memories with and have been so helpful along the way. Thank you Dr. Kara Ross, Dr. Koichi Yamaura, Dr. Jason Fewell, Dr. Sam Funk, and Frank Kyekyeku Nti. I want to say a very special “gracias” to my good friends Verónica and Graciela who have shared each of the ups and downs in life and have been the very best of what friends can be. I am eternally grateful to my mom and my siblings Jocabed and Danny (and their families) for all of their love and the many prayers and words that have sustained me even across such great distances. They always bring joy and peace to my life. I also thank my fiancé, Dave, for his love and support. Lastly, and most importantly, I thank God without whom none of this would be possible. You are my light and my strength and my wisdom.

Funding for the research found in this dissertation came from USDA, NIFA, AFRI Foundation Grant #KS601924, NSF, NSF BCS – 1227451, and the South Central Sun Grant Initiative and Department of Transportation Grant #DTOS59-07-G-00053.

Dedication

To my mom.

Chapter 1 - Introduction

In the last few decades, much attention has been given to environmental degradation and to the ways in which sustainable production can be achieved in agricultural systems. The ecosystem services produced when conservation practices are in place have a value in society, and by creating a market for these services, farmers could receive an incentive to adopt these practices (Ribaud et al., 2010; Whitten and Coggan, 2013). Adoption of conservation practices has increased over the past several years, due in part to the increasing public interest in improving the environment and the voluntary programs that encourage the adoption of conservation practices through monetary incentives and cost-share. These programs primarily focus on water quality and conservation, conservation of soil and land, wildlife habitat, air quality and energy conservation (Claassen et al., 2008).

There is a myriad of available conservation practices that can be adopted in crop production. No-till is one of the most widely adopted practices in the U.S. however, in many cases farmers rotate their tillage practice and continuous no-till might not be as widely adopted (Grandy et al., 2006) . It has been suggested that some no-till farmers may till the ground, specifically in response to economic and seasonal drivers (Llewellyn et al., 2012). While the adoption of no-till provides a variety of benefits, when a no-till-field is tilled some of the benefits, particularly carbon sequestration, may be lost when these are tilled (Grandy et al., 2006). Efforts to intensify conservation may require the adoption of continuous no-till, which is using no-till for all the crops planted in a particular field. The choice of no-till practice may change based on the crop being planted and it is important to identify how exogenous factors affect farmers' choice of tillage at the crop level. Continuous no-till systems may not always

work alone without other practices. In order to control for some pest issues that may arise in continuous no-till systems, farmers may need to intensify conservation on their farm to include other practices such as conservation crop rotations or cover crops. Conservation practices may in many cases be interrelated and provide synergetic benefits. Thus, it is important to encourage farmers not only to adopt a particular practice, but to intensify conservation by adopting groups of practices that are complementary.

A large and growing body of literature has investigated factors affecting the adoption of conservation practices. Numerous modeling approaches have been used to study the adoption of conservation practices and new agricultural technologies and the factors that affect the decision to adopt. Several of these studies have relied on approaches to model the adoption at some point in time and in some cases the level of adoption. These studies compare the differences in the factors between the group of adopters and those of non-adopters at a particular point in time. In many cases, these studies do not consider the process of adoption over time and how some factors not only affect the decision to adopt but also the timing of adoption. By the same token, some factors do not directly restrict the adoption of conservation practices, but they delay the adoption process (Fuglie and Kascak, 2001).

The diffusion of technologies is a gradual process; it takes time for the information about these new practices to be diffused (Jaffe et al., 2002). Given that farmers adopt a conservation practice based on their knowledge or expectations about the benefits of the practice, the timing of information collection (learning) and formation of expectations is important (Au and Kauffman, 2003) and may not be captured in traditional binary adoption models (Burton et al., 2003). In addition, different sources of heterogeneity across farmers make them more likely to adopt at different points in time (Fuglie and Kascak, 2001). Thus, the process and timing of the adoption

of agricultural technologies is important (Hoppe, 2002). Duration models are an important tool that can be used to examine the adoption and the speed of adoption (or disadoption) of agricultural technologies.

Another powerful tool in adoption research is the use of stated choice methods that allow for the examination of attributes that are not present in the market, or if they are present, do not have sufficient variation to estimate their parameters (Louviere et al., 2000). For example, the use of stated choice methods has allowed researchers to study the effect of varying incentive payments/cost-share levels on the adoption, and extent of adoption, of conservation programs. The use of stated choice methods have also furthered the study of other attributes in conservation programs that are of interest for policy makers. Some of these attributes are contract length, risk attributes, payment mechanism, availability of technical assistance or insurance through a conservation program, restrictions on land use, and contract default (Cooper, 2003; Cooper and Signorello, 2008; Espinosa-Goded et al., 2010; Ma et al., 2012; Ruto and Garrod, 2009).

While different model approaches have been used to analyze factors affecting adoption, some important factors are consistently analyzed. One of those factors is risk. Risk is an important component of agricultural production, and it plays an important role in farmers' production decisions, particularly decisions concerning the adoption of conservation practices. The introduction and intensification of conservation on the farm introduces potential risks into the farm operation and can result in shifts in net returns (crop yields and/or costs). When outcomes are uncertain, farmers may be more hesitant to introduce new practices, and additional compensation may be necessary to induce adoption. When studying the adoption of new agricultural technologies, the perception of the probabilities of the distribution of net returns, the variance of net returns, and the strength and direction of risk attitudes are factors affecting that

decision (Marra et al., 2003). The effect of risk in adoption models has been commonly studied under a deterministic framework and distinctive elements of risk have been partially or separately addressed in several studies, however they have not been extensively studied in stated choice applications.

As conservation policies are implemented by different local and federal agencies, understanding farmers' motivations and their thought process when adopting conservation practices is important. In many cases the lack of knowledge about some conservation practices can be a deterrent to adoption (Lamb et al., 2008). Previous findings in the literature suggest that withdrawals from conservation programs take place within the first years of the contract, because expectations regarding private benefits may not be met while implementing those practices (Cattaneo, 2003). Studying farmers' adoption processes provides governments and extension agencies with important insights into the adoption of important conservation technologies and the key aspects that need to be addressed to increase the level of conservation efforts by producers. Understanding these factors is important to ensure the continuation of adoption through the development of programs that are tailored to meet farmers' preferences and constraints.

1.1 Research Objectives

The main purpose of this this dissertation is to study the factors affecting farmers' decisions to adopt conservation practices. Specifically, the objectives of this research are:

- i) To identify factors such as farm management characteristics, farmers' attitudes, farmers' risk aversion, and socio-demographic factors that impact farmers' choice of no-till (NT),

Strip-till (ST), and Conventional tillage (CT) for dryland corn, wheat and soybean production in Kansas.

- ii) To examine farmers' willingness to adopt and intensify in-field conservation practices under risk using a stated preference approach.; and
- iii) To examine factors affecting the adoption and the time of adoption of conservation practices in Kansas and to gain insights regarding the time-path diffusion of these conservation practices since their introduction.

The following section presents an overview of the three essays that comprise this dissertation. The overviews present a summary of the methods used to meet the research objectives outlined above. In addition, the overview of the essays presents some of the results that emerged from each research objective.

1.1.1 First Essay: Modeling the choice of tillage used for dryland corn, wheat and soybean production by farmers in Kansas

In recent years, great attention has been placed on conservation systems for agricultural production, especially conservation tillage. Conservation tillage offers economic and soil quality benefits, yet conventional tillage remains the prevailing system in some regions. The purpose of this essay was to identify the factors affecting farmers' choice of tillage practice at the crop level using data collected from a survey conducted face to face. Farmer's choice of No-till (NT), Strip-till (ST) and Conventional tillage (CT) was modeled for dryland corn, wheat and soybean production in Kansas using a multinomial logit model. Studies on tillage adoption are commonly conducted at the farm level, or on a particular crop. This study contributes to the

body of literature by modeling the adoption of different tillage practices at the crop level. An empirical model that accounts for farm management characteristics, farmers' attitudes, farmers' risk aversion, and socio-demographic factors was used. In addition, the effect of crop rotation decisions on tillage practice adoption was studied. Including crop rotation decisions provided a mechanism to capture the interconnectedness of production decisions.

An important finding to emerge from this study is farmers' response to risk, where risk averse farmers were found to be more likely to use no-till practices. This may indicate that no-till practices are believed by farm managers in this study as a risk reducing practice. This study also provides evidence that some no-till adopters change their tillage as crop choice changes. In addition, factors such as baling and grazing of crop residue, crop acreage, and farmers' promptness to adopting new technologies were also found to be significant factors affecting farmers' decisions. A better understanding of the factors affecting the adoption of tillage practices at the crop level may facilitate the development of policies and educational programs to encourage the adoption of conservation tillage methods.

1.1.2 Second Essay: Adoption of in-field conservation practices under risk

The second essay focuses on the adoption of conservation on the farm and the factors that may affect farmer's decision to adopt conservation using a stated choice experiment. For the stated choice experiment, farmers evaluated twelve different conservation contracts. This study expands on previous research by examining conservation program attributes that have not been widely evaluated in the conservation adoption literature to-date, such as incentive payments, incentive payment mechanisms and off-farm environmental benefits from conservation. This essay also examined the risk associated with the variability of net returns and its effect on

farmers' willingness to adopt conservation practices using a non-linear extended expected utility model that combines aspects of expected utility and prospect theory (Hensher et al., 2011). This approach results in a non-linear utility specification within the random utility model and it is more flexible because it allows for the estimation of utility parameters for net returns, farmer's subjective judgment of probabilities, and farmers' risk attitudes.

Farmers were found to exhibit risk aversion with respect to changes in net returns from the adoption of new conservation practices. This study also found significant risk premiums for the enrollment in the conservation contract under the different probability weighting specifications. Findings suggest farmers require approximately 3% of their current net returns as a payment for bearing the risk of potential variability in net returns under a conservation contract. The results also suggest that farmers make limited use of subjective probabilities when evaluating risk in net returns under the conservation contract. Results also provided evidence suggesting a lower likelihood of adoption, for the same level of incentive payment, if the mechanism through which the incentive payment was offered was a carbon credit program (as opposed to a federally-run program). Findings in this study provide support for the importance of considering uncertainty in outcomes when designing incentive programs to encourage the adoption of in field conservation systems.

1.1.3 Third Essay: Modeling the factors affecting farmers' timing of adoption of in-field conservation cropping practices

The diffusion of new technologies is a gradual process; it takes time for the information about these new practices to be diffused (Jaffe et al., 2002). While the first essay examines adoption at a point in time, it is also possible to examine adoption over time using a dynamic model. Using

duration models allows for the temporal aspect to adoption and the heterogeneity in the timing of adoption to be accounted for (Abdulai and Huffman, 2005). The third essay examines the timing of adoption of three conservation practices: continuous no-till, cover crops, and VRA of inputs. The timing of adoption is measured as the time it takes for farmers to adopt a practice since they first started managing the farm or since the introduction of the practice if the practice became available after the farmer starting farming. This study seeks to uncover the effect of farmers' demographics (age, education), farmer characteristics and farm management characteristics (risk aversion, off-farm work, percentage of income from crop production) and farmers' attitudes (stewardship, innovation), and the adoption of previous conservation practices on the duration of farmers decision to adopt a particular practice. In addition, this study seeks to investigate how conservation on the farm affects the speed of adoption of other conservation practices.

Findings in this study suggest that the adoption of certain practices delay the adoption of other conservation practices. For example, the adoption of conservation crop rotation and VRA of inputs were found to delay the adoption of continuous no-till, and the adoption cover crops was also found to delay the adoption of VRA of inputs. In addition, the findings in this study suggest that risk aversion is not a significant factor delaying the speed of adoption of continuous no-till. Similar to the first paper, it is possible that farmers do not see no-till as a risky practice, thus risk aversion may not affect its adoption or speed of adoption. However, risk aversion was found to delay the adoption of cover crops and VRA of inputs. In addition, the results in this study suggest that farmers who considered themselves innovators adopt the three conservation practices at a faster rate than their counterparts. This study provides insight into the factors affecting the speed of adoption of some in field conservation practices. Understanding what factors delay adoption can allow conservation agencies and extension efforts to tackle such

factors in order to accelerate adoption.

References

- Abdulai, A., and W.E. Huffman "The diffusion of new agricultural technologies: The case of crossbred-cow technology in Tanzania." *American Journal of Agricultural Economics* 87 (2005):645-59.
- Au, Y.A., and R.J. Kauffman "What do you know? Rational expectations in information technology adoption and investment." *Journal of Management Information Systems* 20 (2003):49-76.
- Burton, M., D. Rigby, and T. Young "Modelling the adoption of organic horticultural technology in the UK using Duration Analysis." *Australian Journal of Agricultural and Resource Economics* 47 (2003):29-54.
- Cattaneo, A. "The pursuit of efficiency and its unintended consequences: contract withdrawals in the environmental quality incentives program." *Review of Agricultural Economics* 25 (2003):449-69.
- Claassen, R., A. Cattaneo, and R. Johansson "Cost-effective design of agri-environmental payment programs: US experience in theory and practice." *Ecological Economics* 65 (2008):737-52.
- Cooper, J.C. "A joint framework for analysis of agri-environmental payment programs." *American Journal of Agricultural Economics* 85 (2003):976-87.
- Cooper, J.C., and G. Signorello "Farmer premiums for the voluntary adoption of conservation plans." *Journal of Environmental Planning and Management* 51 (2008):1-14.
- Espinosa-Goded, M., J. Barreiro-Hurlé, and E. Ruto "What do farmers want from Agri-environmental scheme design? A choice experiment approach." *Journal of Agricultural economics* 61 (2010):259-73.
- Fuglie, K.O., and C.A. Kascak "Adoption and diffusion of natural-resource-conserving agricultural technology." *Review of Agricultural Economics* 23 (2001):386-403.
- Grandy, A., G. Robertson, and K. Thelen "Do productivity and environmental trade-offs justify periodically cultivating no-till cropping systems?" *Agronomy Journal* 98 (2006):1377-83.
- Hensher, D.A., W.H. Greene, and Z. Li "Embedding risk attitude and decision weights in non-linear logit to accommodate time variability in the value of expected travel time savings." *Transportation Research Part B: Methodological* 45 (2011):954-72.
- Hoppe, H.C. "The timing of new technology adoption: theoretical models and empirical evidence." *The Manchester School* 70 (2002):56-76.

- Jaffe, A.B., R.G. Newell, and R.N. Stavins "Environmental policy and technological change." *Environmental and Resource Economics* 22 (2002):41-70.
- Lamb, D.W., P. Frazier, and P. Adams "Improving pathways to adoption: Putting the right P's in precision agriculture." *Computers and Electronics in Agriculture* 61 (2008):4-9.
- Llewellyn, R.S., F.H. D'Emden, and G. Kuehne "Extensive use of no-tillage in grain growing regions of Australia." *Field Crops Research* 132 (2012):204-12.
- Louviere, J.J., D.A. Hensher, and J.D. Swait *Stated choice methods: analysis and applications* Cambridge University Press, 2000.
- Ma, S., S.M. Swinton, F. Lupi, and C. Jolejole-Foreman "Farmers' Willingness to Participate in Payment-for-Environmental-Services Programmes." *Journal of Agricultural Economics* 63 (2012):604-26.
- Ruto, E., and G. Garrod "Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach." *Journal of Environmental Planning and Management* 52 (2009):631-47.

Chapter 2 - Modeling the choice of tillage used for dryland corn, wheat and soybean production by farmers in Kansas

2.1 Introduction

In recent years, great attention has been placed on conservation systems for agricultural production. The Soil Science Society of America (SSSA, 2012) defines conservation tillage as a sequence of tillage operations that leaves at least 30% of crop residue on the soil surface and whose objective is to diminish the loss of soil and water. Similarly, reduced tillage (RT) practices consist in reducing the number of tillage passes, resulting in a soil coverage ranging from 15 to 30 percent (EPA, 2013; SSSA, 2012). Conservation tillage practices include no-tillage (NT) and strip tillage (ST) and have proven to be beneficial for the soil. Some of the benefits linked to conservation tillage systems are: increase in soil organic carbon; soil microbial biomass; reduction of wind and water erosion; and enhancement of nutrient cycling (Blanco-Canqui et al., 2009a; Campbell et al., 2001; Kladivko, 2001; Kushwaha et al., 2001; Lal 1999; Paustian et al., 2000; Wang et al., 2011; Zibilske et al., 2002). Another advantage is conservation of soil moisture (Daniel et al., 1999; Blevins et al., 1971), which may allow farmers to reduce the number of fallow periods to increase production intensity in dryer areas while also reducing the risk from droughts (Ding et al., 2009). Overall, conservation tillage practices have demonstrated to provide a better alternative for enhancing the physical condition of the soil and to increase carbon sequestration (West and Marland, 2002; West and Post, 2002).

Notwithstanding the benefits associated with conservation tillage, some negative aspects have also been reported in the literature. In some regions, retention of moisture by crop residue

on the soil surface could increase the incidence of diseases (Anaele and Bishnoi, 1992, Bockus and Shroyer, 1998) and result in lower yields (Heer and Krenzer, 1989). The need to control weeds chemically and the potential for an increase in diseases with NT could result in higher chemical costs that in some cases may offset the savings from labor and machinery costs (Williams et al., 2000; Williams et al., 2012). A study by Kaval (2004), who compared the profitability and production costs of 198 NT and conventional tillage (CT) systems in the literature, suggested that NT is the least costly system. However, yields and cost savings from NT systems vary across regions. In the short-term, NT practices could result in higher costs and increase risk, due in part to the purchasing of new equipment (or modifications) and variability of yields during the adoption period (Epplin and Tice, 1986). However, increased soil stability and reduction of the risk of soil erosion, particularly in row crops with limited biomass cover, can be observed in the long-term (Alberts et al., 1985; Blanco-Canqui et al., 2009b).

Although conservation tillage may be more beneficial to the environment, conventional tillage still remains the prevailing tillage system for some crops in Kansas. A 2010 survey of tillage practices in 23 Kansas counties showed that conventional tillage was the predominant tillage practice in wheat production, being used on approximately 56% of land planted to wheat (Kansas State University Research & Extension, 2010). Only 27% of the land was under conservation tillage practices and 12% under RT, which consisted of tillage practices that leave 15-30% crop residue after planting. Conversely, 56% of corn land was under conservation tillage, while 25% was under conventional tillage and 17% under RT. Soybean land was largely planted using conservation tillage practices (62%), while 22% of the land remained under conventional tillage and 14% under RT (Kansas State University Research & Extension, 2010).

A study by Langemeier (2010) found that NT farms in Central Kansas were generally larger and more profitable. These farms produced less wheat and more feed grains and had lower machinery and labor costs than farms with other tillage systems. The adoption of conservation tillage practices has changed the dynamics of crop production. According to Gasper and Langemeier (2010), corn and soybean production has increased due in part to the adoption of conservation tillage practices, which has allowed soils to maintain more moisture in the dryer areas of Kansas. NT practices can facilitate double cropping and increase the flexibility of crop rotations (Sandretto, 2001). Langemeier (2010) also suggested that using NT improved farms flexibility by allowing them to include feed grains and oilseeds into their crop rotations.

Despite the benefits associated with NT, farmers may choose not to adopt if they believe NT requires a big technological adjustment (Schneider et al., 2010). Hence, the choice of tillage practice is a critical decision for any farm enterprise. To date, the literature has predominantly focused on studying the adoption of conservation tillage at the farm level (Belknap and Saupe, 1988; D’Emden et al., 2008; Davey and Furtan, 2008; Gould et al., 1989; Shortle and Miranowski, 1986; Vitale et al., 2011)¹. However, tillage decisions may be crop-specific. Farm operators could use NT for some crops, but they may face constraints to adopting NT in other crops, because the investment in management skills for these crops is higher (Epplin and Tice, 1986).

¹ Fuglie (1999), Soule, Tegene, and Wiebe (2000), and Uri (1997) focused their study of conservation tillage adoption on corn production.

2.2 Objective

The objective of this paper is to identify factors such as farm management characteristics, farmers' attitudes, farmers' risk aversion, and socio-demographic factors that impact farmers' choice of No-till (NT), Strip-till (ST), and Conventional tillage (CT) for dryland corn, wheat and soybean production in Kansas. A multinomial logit model was used to study farmers' choice of tillage practice at the crop level. Dryland corn, wheat and soybeans were analyzed because of their economic importance to agriculture in Kansas. Knowing the factors affecting the adoption of tillage practices at the crop level may facilitate the development of policies and educational programs to encourage the adoption of conservation tillage methods.

2.3 Literature Review

Ervin and Ervin (1982) found studies looking at factors influencing the adoption of soil conservation practices dating back to the 1950s. To date, numerous studies have looked at factors affecting the adoption of different tillage systems, in particular conservation tillage, using different methodologies and sets of explanatory variables. Commonly, models used in the literature to examine farmers' adoption of tillage systems have included logit, probit, ordinary least squares and multinomial logit models.

Most frequently, studies have looked at the adoption of a particular tillage technology as a binary response using logit or probit models. Belknap and Saupe (1988) looked at the adoption of no-plow tillage practices among farmers in Wisconsin. Their findings suggest that the decision to adopt no-plow tillage was positively influenced by farm size and percentage of land owned, but negatively affected by the level of risk aversion. Soule et al. (2000) studied the adoption of conservation tillage as affected by the type of lease arrangement. In a base model

where no differentiation was made between types of renter, land ownership, land tenure had no statistical significance in the model. However, when a distinction was made between cash-renters and share-renters, findings suggest that the farmers in the former group are less likely to adopt conservation tillage. Rahm and Huffman (1984) studied adoption and adoption efficiency of RT among corn farms in Iowa. They modeled the efficiency of adoption as the difference between the actual farm adoption decision and the predicted probability of adoption, which represents the utility maximizing decision. They found that characteristics of the cropping systems affect the decision to adopt RT, while human capital decisions affect the efficiency of the decision of tillage technology adoption. Using data collected in Iowa for the National Resource Inventory on farming practices, Pautsch et al. (2001) estimated a model on the adoption of conservation tillage and the potential for carbon sequestration. Their results suggest that some climate variables may affect the decision to adopt conservation tillage. Davey and Furtan (2008) investigated the adoption of conservation tillage by prairie farmers in Canada using data from an agricultural census. Variables found to explain the adoption of conservation tillage were farm size as well as soil and weather variables. A study by D'Emden et al. (2008) also looked at the adoption of NT in Australia and found that perception of erosion reduction associated with NT practices did not explain adoption. However, other crop production benefits associated with NT practices and extension information increase the likelihood of adoption. Banerjee et al. (2009) studied the adoption of conservation tillage practices and herbicide resistance cotton using a logit model. Their findings did not find evidence of the use of herbicide resistance seed as a factor affecting the adoption of conservation practices.

Other studies have looked at the adoption of multiple tillage practices using multinomial logit models. Fuglie (1999) conducted a study looking at factors affecting the selection of CT,

NT and other conservation tillage practices (mulch or ridge till) in corn production, in the Cornbelt region, using data from a survey conducted by the USDA. In their study, conservation compliance was found to be a significant factor in determining the selection of NT. Their findings also suggest that farm size was a significant variable affecting the choice of tillage system, while college education and operator experience were not significant factors in the adoption of NT. Pereira de Herrera and Sain (1999) studied the adoption of CT, NT and RT by corn producers in Panama. Their results varied among the studied regions. The proportion of land under livestock and the acreage of corn had a positive effect on the decision to adopt NT and RT for some regions and had a negative effect in other regions. Land ownership was not significant in explaining the decision to adopt a particular tillage system.

The adoption of conservation tillage and the intensity of adoption have also been studied using two stage models where the probability of adoption is assessed in the first stage and intensity of adoption in the second stage. Uri (1997) assessed the adoption of conservation tillage in corn production using variables related to the farm and farmland characteristics and other variables related to agricultural input use from a survey conducted by USDA-NASS. In their study, cash grain farmers were found to be more likely to adopt NT practices. A slightly different approach was used by Gould et al. (1989) and Traore'et al. (1998). In their two stage model, a farmer's perception or awareness of an environmental degradation was assessed in the first stage and in the second stage they modeled the adoption of conservation tillage as affected by the farmer's perception of an environmental problem.

Additionally, some research has been conducted looking at the adoption of conservation tillage as part of a bundle of multiple practices. Wu and Babcock (1998) conducted a joint analysis of the choice to adopt conservation tillage, rotation and soil testing in Central Nebraska.

Other studies looking at the choice of conservation tillage in a joint framework are Cooper (2003), who used a multinomial probit model to estimate the use and nonuse of different practices including conservation tillage; and Bergtold and Molnar (2010) who examined factors affecting the adoption of conservation tillage and other practices in the Southeast using a multinomial logit approach.

Most of these studies have included farmers and farm household characteristics, farm management characteristics and attitudinal variables. Additionally, other studies have included farm biophysical and climatic data. A study by Pautsch et al. (2001) on the adoption of conservation tillage using a logit model included climatic and land characteristic but did not included farm characteristic or attitudinal factors. Nonetheless, attitudinal factors and farm structure are important determinants in the decision to adopt environmentally-friendly practices (Welsh and Rivers, 2011).

Past studies on the adoption of NT or ST examined the choice of tillage when practices were not widely embraced by producers. These practices have now been more widely adopted and it is possible that changes in perception have occurred. The adoption of conservation tillage practices, especially NT, has expanded with the dissemination of knowledge (i.e. due to new research findings; famers' experiences; interaction of adopters and non-adopters; and the improvement of NT equipment) (Coughenour, 2003). Hence, it is possible that there may be some changes in the way farm household and farm management characteristics impact the choice of tillage practices for crop production.

Studies on tillage adoption are commonly conducted at the farm level, or on a particular crop. This study contributes to the body of literature by modeling the adoption of different tillage practices at the crop level for dryland corn, wheat and soybean production for medium to

large size farms. An empirical model that accounts for farm management characteristics, farmers' attitudes, farmers' risk aversion, and socio-demographic factors is used. In addition, the effect of crop rotation decisions on tillage practice adoption is studied. Including crop rotation decisions provided a mechanism to capture the interconnectedness of production decisions. This study found new insights into how risk-averse farmers' attitudes affect the adoption of conservation tillage practices compared to previous literature.

2.4 Data and methods

2.4.1 Model

The decision of tillage practice at the crop level for dryland corn, wheat and soybeans is modeled empirically using a random utility framework that allows the model to account for economic motivations, as well as other farm and farm management characteristics that may play an important role in farmers' motivation to adopt a particular practice (Skaggs et al., 1994; Robinson et al., 1984). Following this approach, farmer i 's utility (U_{ij}) from the adoption of tillage practice j can be denoted as a function of farm management characteristics (\mathbf{x}_i), attitudinal factors ($\mathbf{\Gamma}_i$), farmer's risk aversion (\mathbf{r}_i), and socio-demographic factors (\mathbf{z}_i). Farmer's subjective utility from the adoption of a tillage practice can be expressed as $U_{ij} = V_{ij}(\mathbf{x}_i, \mathbf{\Gamma}_i, \mathbf{r}_i, \mathbf{z}_i) + \varepsilon_{ij}$, where V_{ij} represents the systematic component of utility, explained by observed factors, and ε_{ij} is a random component containing unobserved factors affecting the utility. Farmers compare the utility derived from each tillage practice available from their choice set ($j = NT, ST, CT$) and choose the practice that maximize their utility, i.e.

$U_{ij} = \max(U_{i0}, \dots, U_{iJ})$ (Louviere et al., 2000). If the random component of the utility is distributed Extreme Value type I and assuming linearity of the utility function, the choice model becomes (McFadden, 1973):

$$(2.1) \quad \mathbf{P}_i(T_i = j | \mathbf{X}_i) = \frac{\exp[\mathbf{X}_i' \boldsymbol{\beta}_j]}{1 + \sum_{j=1}^J \exp[\mathbf{X}_i' \boldsymbol{\beta}_j]}, \quad \text{for } j = NT, ST, CT; \quad i = 1, \dots, N$$

where T_i is a polychotomous index denoting the choice of tillage practice by farmer i , $\mathbf{X}_i = (\mathbf{x}_i, \boldsymbol{\Gamma}_i, \mathbf{r}_i, \mathbf{z}_i)$ is a $(k \times 1)$ vector containing the observed explanatory variables for the i^{th} individual, and $\boldsymbol{\beta}_j$ is a $(k \times 1)$ vector of unknown parameters for tillage practice j . Marginal effects $(\partial P_i / \partial X_i)$ where P represents the probability that farmer i chooses practice j were derived following Greene (2012) and asymptotic standard errors for the marginal effects were computed using the delta method (Greene, 2012).

2.4.2 Survey and Data Description

A survey was administered by Kansas State University, the USDA, and the National Agricultural Statistics Service (NASS) from November 2010 to February 2011 in the northeast, south central and western regions of Kansas. Farmers with 260 or more acres in size and a minimum of \$50,000 in gross farm sales were randomly selected and contacted to participate in the survey. The survey was conducted face to face by USDA-NASS enumerators. A total of 485 farmers were initially contacted, of which 290 completed the survey and 38 could not be located, were out-of-business, or did not farm; resulting in a response rate of 65%. The sample of farmers

surveyed is relatively representative of farmers' demographics in Kansas. The average age of the farm operators as reported in the 2007 U.S. Census of Agriculture is 57.7 years and the average market value of agricultural products is \$219,944 (National Agricultural Statistics Service - USDA, 2007). The average age of the sample of farmers used in this study was 55.87 and the category for market value of agricultural products chosen with the highest frequency by respondents was \$200,000 to \$399,999. The average farm size reported by farmers in the survey was 2,123 acres, larger than the general population (707 acres) since the survey focused on medium to larger farmers. Hence, results in this study should be interpreted as representing tillage decisions by medium to large farm operators in Kansas.

The survey was used to gather data on respondents' farm management characteristics, farmers' attitudes, farmers' risk version, and socio-demographic information. Farmers provided information on tillage practices used on dryland corn, wheat and soybean. These crops were selected for this study due to the economic importance of these crops in the state of Kansas. Respondents were asked questions relevant to the agronomic practices for each particular crop, including their predominant crop rotation patterns, and if they graze or bale their crop residue. Respondents also provided information on the acreage planted, as the average values from the past three years. While no questions were asked regarding farmers' production costs, respondents were asked to indicate whether they considered themselves low cost producers using a Likert scale. In addition, questions were included to determine the percentage of household income from farming operations; total acreage of land owned and rented from others; and if the farmer had a conservation plan. Farmers' attitudes such as promptness in adopting new technology and whether maximizing farm profits was more important than environmental stewardship were elicited using a Likert scale. To elicit farmers' risk preferences, farmers were

asked to self-identify their level of risk aversion by indicating how they thought their neighbors would describe their (the interviewed farmers) risk taking behavior with respect to their farm operation. The respondents were presented with six options to this risk taking behavior question. Farmers who considered being perceived by their neighbors as an “extreme risk avoider” or “cautious” were classified as risk-averse. Farmers who considered they were perceived as “a real gambler,” “enjoy taking risks,” “not concerned about risk” or “willing to take risk after adequate research” were denoted as risk-takers or risk-neutral. Data on farmers’ demographics collected included age and education.

Tillage practices were analyzed at the crop level for dryland corn, wheat and soybeans. Information regarding the tillage practices performed by farmers on their planted crops was added to form three distinct categories for the analysis here. The NT and ST category consisted of farmers who exclusively responded that they used no-till or strip-till on their crop fields. The CT category comprised reduced tillage, harrow and the combinations of strip tillage-harrow, and harrow-chisel as well as moldboard plow, disc, cultivator, ripper and practices where these tillage operations were done in different combinations.

Of the sampled individuals growing dryland corn, 18% used CT, 16% ST and 67% used NT. Twenty-two percent of the farmers used CT in wheat production, while 25% used ST and 53% used NT. For dryland soybean production, 18% of the sampled individuals had their land under CT, 18% under ST and 65% under NT (Table 2.1). The distribution of tillage practices was contrary to what was expected considering the results of the 2010 survey of tillage practice in Kansas previously referenced in this paper, in which a larger percentage of conventional tillage was observed. Differences in the distribution may arise since the Kansas tillage practice survey is based on the number of acres under each particular practice as opposed to the number

of farmers using that particular practice. In addition, data from the 2010 Kansas tillage practice survey was available only for 23 counties located mainly in the central and northeast regions of the state. The data used in this study included observation from farmers in western Kansas where NT practices are more commonly used.

Table 2.1 Adoption percentage of tillage practices by crop in Kansas

	Corn	Wheat	Soybean
NT	67%	53%	65%
ST	16%	25%	18%
CT	18%	22%	18%
N. Observations	177	165	114

NT=No tillage, ST= Strip tillage, CT= Conventional tillage

2.4.3 Explanatory Variables used in the Analysis

Variables affecting farmers' choice of tillage practice at the crop level were grouped into four categories: farm management characteristics, farmer' attitudes, farmers' risk aversion, and socio-demographic factors. These variables have been generally identified in the literature as important determinants in the adoption of conservation practices (Baumgart-Getz et al., 2012; Prokopy et al., 2008). Variable descriptions and their descriptive statistics are reported in Table 2.2.

Farm management characteristics evaluated are crop rotation, baling or grazing of crop residue, acreage planted to the crop being examined, if the farmer is a low cost producer, on-farm income (percentage of household income from the farming operation), percentage of land rented, and if the farmer has a conservation plan². Crop rotation variables were included as crop rotation and tillage decisions may be interdependent. Crops in the rotation were grouped into three crop categories: corn/sorghum, legumes (i.e. soybeans, alfalfa) and cereals (i.e. wheat, rye). A dummy variable was used to indicate the crop type preceding the crop of interest in the rotation. The same crop type was used as the base scenario (i.e. in the corn model, the corn/sorghum category was used as the base scenario). Refer to Table 2.2 for additional explanation. Farmers who rotated their crops were expected to be more likely to adopt conservation tillage than farmers in a monoculture (Vitale et al., 2011). It was also hypothesized that crop rotations including corn/sorghum and soybean would result in a higher likelihood of using NT practices because of these crops sensitivity to moisture stress and NT potential to

² A variable indicating whether farmers have a conservation plan was included as an alternative to a variable indicating whether they receive cost-share or incentive payments (for adopting conservation tillage) due to lack of variation within the data which makes it difficult to estimate its effect.

enhance soil moisture retention (Baumhardt and Jones, 2002; Norwood, 1999). Farmers may also use NT to improve water retention in rotations with wheat in dryer areas. As a whole, the effect of crop rotation was expected to be significant if farmers take a systems approach where all the elements in the production systems are considered when deciding what tillage practices to adopt.

Farmers who graze or bale their crops were expected to be more likely to adopt CT. Grazing and crop residue removal could result in soil compaction problems, CT practices may be used as a tool to break the soil and reduce soil compaction (Hamza and Anderson, 2005; Vitale et al., 2011). The acreage of the crop planted was expected to have a positive effect on the adoption of NT because of the potential efficiency gains, particularly labor savings (Prokopy et al., 2008; Langemeier, 2010). Costs considerations are a major factor farmers need to consider when making decisions regarding what practices to adopt on their farm (Lichtenberg, 2004; Sijtsma et al., 1998). Due to lack of cost data, this study included a proxy to measure the effect of cost as a dummy variable, which takes on a value of 1 if the farmer indicated they were a low cost producer and 0 otherwise. Low cost producers have a greater incentive to adopt cost saving practices. Conservation tillage practices result in lower labor and fuel costs, but they could also result in higher herbicide costs (Williams et al., 2012; Mueller et al., 1985). Production cost advantages will then depend on input allocation and prices (Rahm and Huffman, 1984), but ultimately farmers' decision to adopt is affected by their perception of how costly the practice is.

Table 2.2 Definition of variables and summary statistics

Variable	Corn	Wheat	Soybean	Description
Rotation with corn/sorghum	---	0.220 (0.414)	0.761 (0.426)	The crop preceding in the main rotation is corn or sorghum (1 = yes, 0 = no).
Rotation with legume	0.346 (0.476)	0.351 (0.477)	---	The crop preceding in the main rotation is a legume (1 = yes, 0 = no).
Rotation with cereal crop	0.559 (0.497)	---	---	The crop preceding in the main rotation is a cereal (e.g. wheat, rye) (1 = yes, 0 = no).
Graze crop residue	0.447 (0.497)	0.149 (0.356)	0.257 (0.437)	Farmer grazes the crop or crop residue of the crop modeled (1 = yes, 0 = no).
Bale crop residue	0.078 (0.268)	0.274 (0.446)	---	Farmer bales crop residue of the modeled crop (1 = yes, 0 = no).
Acreage planted of crop being examined	405.447 (448.33)	581.875 (534.54)	435.195 (372.65)	Number of acres planted to the crop modeled averaged over the past three years.
Low cost producer	0.824 (0.381)	0.853 (0.355)	0.794 (0.404)	The farm operator is a low cost producer (1 = yes, 0 = no).
On-farm income percentage	69.318 (33.59)	67.815 (34.78)	66.991 (32.5)	Percentage of household income derived from the farming operation.
Percentage of land rented	57.824 (30.97)	55.907 (31.49)	58.037 (31.06)	Percentage of total land rented or leased from others.
Conservation plan	0.804 (0.397)	0.815 (0.388)	0.867 (0.340)	Existence of a conservation plan for the farm (1 = yes, 0 = no).
First time technology adopter	0.810 (0.392)	0.780 (0.414)	0.779 (0.415)	Farm operator usually adopts new technology (e.g. no-till, new seeds, etc.) before neighbors (1 = yes, 0 = no)
Profit motivation	0.531 (0.499)	0.542 (0.498)	0.549 (0.498)	Maximizing farm profit is more important than environmental stewardship to the farm's operator (1 = yes, 0 = no).
Risk-averse	0.391 (0.488)	0.381 (0.486)	0.407 (0.491)	Risk taking behavior in farm management decisions (1 = risk averse, 0 = otherwise)
Age	55.486 (12.04)	55.494 (11.78)	54.451 (11.52)	Farmer's age in years.
Education	0.307 (0.461)	0.321 (0.467)	0.292 (0.455)	Farm operator has a college degree (1 = yes, 0 = no).
<i>Number of observations</i>	<i>177</i>	<i>165</i>	<i>114</i>	

Numbers in parenthesis represent the standard deviations of the estimates. The standard deviation of binary variables was calculated as: $\sqrt{\rho(1-\rho)}$ where ρ is mean value of the binary variable.

There was not a prior expectation with respect to the effect of on-farm income on tillage decisions. Farmers who depend more heavily on farm income may be more interested in conservation practices to maintain and enhance the productivity of their land. However, this variable could also be capturing some of the effect of off-farm labor. Farmers who work more off the farm could have an incentive to adopt NT practices because of labor savings (Gould et al., 1989). The percentage of land rented was hypothesized to have a negative impact on the adoption of NT practices. Tenants have a shorter planning horizon and potentially lower interest in the long-term productivity of rented land (Soule et al., 2000). Farmers with a conservation plan were expected to be more likely to use NT practices on all their crops.

Attitudinal variables consisted of dummy variables denoting if the farmer was a first-time technology adopter and if stewardship was more important than profit maximization to the farmer. Farmers with these characteristics were expected to have a better attitude towards conservation (or the adoption of new practices) and to be more likely to use conservation tillage practices (NT and ST).

Farmers' risk aversion was captured through the use of a dummy variable taking a value of 1 if the farmer was risk-averse and 0 otherwise. The adoption of NT practices may require new machinery, knowledge, and management skills, which when coupled with the potential variability in yields, may increase the risk of using NT for some farm operators (Larson et al., 2001). Several studies have attempted to determine which tillage system would be preferred by farmers under different risk preferences by estimating the distribution of returns and/or using stochastic dominance analysis. Some of these studies have suggested that risk-averse farmers would prefer NT or RT over CT practices (Ribera et al., 2004; Williams et al., 2000). In contrast, other studies have found that NT practices might not be an attractive practice for risk-averse

farmers (Varner et al., 2011; Larson et al., 2001). While these studies provided important insights into what tillage practice risk-averse farmer would prefer, they do not provide evidence into farmers' choices given their perceptions of crop returns and variance of returns under each tillage practice. In the past, when NT or ST practices were not widespread, it was possible that risk-averse farm operators were less likely to adopt ST or NT practices. As conservation tillage practices have become more widespread and farmers have more knowledge about their benefits, farmers' perceptions regarding the risk-mitigating potential of conservation tillage practices may have changed.

Socio-demographic factors included in the model were age and education. Education was denoted by a dummy variable taking a value of 1 if the farmer had a college degree and 0 otherwise. Farmers with a college degree were expected to be more likely to adopt conservation practices because of a higher exposure to and use of information. Age was expected to be positively related to the use of tillage practices more conventional in nature. Younger farmers may be more eager about trying newer technologies (D'Souza et al., 1993)³.

2.5 Results

Parameter estimates and statistical measures from the multinomial logit model of tillage adoption in dryland corn, wheat and soybean production are reported in Table 2.3. Marginal effects representing the change in the probability of choosing a particular tillage system given a one unit change in an explanatory variable are reported in Table 2.4. The models of tillage choice in corn

³ Information on race and gender was not included in the model given the limited variation across respondents.

and soybean performed better than the model of tillage choice in wheat. The percentage of correct predictions of the choice of tillage use in corn was 71% and 81% for soybean, while 55% of the choices were correctly predicted for wheat. Across the three crops, the decision to use NT had the highest rate of correct predictions with 74% for corn, 83% for soybeans, and 56% for wheat (Table 2.3). The McFadden Pseudo R-squared for the corn, soybean, and wheat models were 0.16, 0.36, and 0.06, respectively.

Crop rotation was not found to be a statistically significant factor in the decision of tillage practice for corn, wheat or soybean production. This result supports the idea that tillage decisions are crop-specific, and not connected to considerations of the entire cropping system dynamics, particularly crop rotations. Previous research in the literature suggested that practices may be seen by farmers independently and adopted in a stepwise form (Bergtold and Molnar, 2010; Byerlee et al., 1986). However, the importance of managing the farm as an integrated system in order to exploit the synergy benefits from practices that are interrelated cannot be undermined (Ikerd, 1993). It was also worth noting that approximately 48% of the farmers who reported using NT in corn, wheat, or soybeans had not adopted the use of continuous NT in rotations with these crops. For instance, several farmers reported using NT for corn and/or soybeans, but not for a wheat crop in the same rotation. An interesting observation to emerge from this result is that while NT is widely used by crop producers, continuous NT has not been fully adopted. This finding is in agreement with Williams et al. (2000); and with Grandy et al. (2006), who suggested that some NT systems in the U.S. are periodically tilled.

Table 2.3 Parameter estimates for the choice of tillage system in dryland corn, soybean and wheat

	Corn		Wheat		Soybean	
	NT	ST	NT	ST	NT	ST
Intercept	1.9883 (2.148)	-0.6440 (2.741)	0.5822 (1.724)	1.0091 (1.916)	0.2612 (2.728)	0.7497 (3.224)
Rotation with corn/sorghum	---	---	-0.4060 (0.588)	-0.2670 (0.643)	1.2841 * (0.746)	1.0808 (0.948)
Rotation with legume	-0.0114 (0.782)	-0.6515 (1.038)	0.0849 (0.546)	-0.7203 (0.634)	---	---
Rotation with cereal crop	0.5021 (0.780)	-0.2097 (0.991)	---	---	---	---
Graze crop residue	0.2158 (0.472)	1.3274 ** (0.616)	-0.3197 (0.634)	-0.4280 (0.742)	1.5627 (1.096)	2.1223 * (1.230)
Bale crop residue	-1.4513 * (0.796)	-0.8364 (0.951)	-0.6182 (0.527)	-0.0830 (0.592)	---	---
Acreage planted of crop being examined	0.0021 ** (0.001)	0.0023 ** (0.001)	0.0003 (0.000)	0.0005 (0.000)	0.0057 *** (0.002)	0.0034 (0.002)
Low cost producer	0.1748 (0.551)	1.0086 (0.920)	0.6330 (0.577)	0.6289 (0.681)	0.4935 (0.833)	2.6085 * (1.457)
On-farm income percentage	-0.0173 ** (0.008)	-0.0216 ** (0.009)	-0.0098 (0.007)	-0.0124 (0.008)	-0.0039 (0.011)	0.0020 (0.013)
Percentage of land rented	-0.0084 (0.008)	-0.0068 (0.011)	0.0015 (0.008)	-0.0036 (0.008)	-0.0025 (0.012)	-0.0282 ** (0.014)
Conservation plan	1.2869 ** (0.523)	0.3287 (0.644)	0.7055 (0.535)	0.5078 (0.602)	1.8203 * (0.954)	-1.2117 (0.999)
First time technology adopter	0.3311 (0.599)	-1.2963 * (0.681)	1.0588 ** (0.511)	0.3170 (0.558)	1.3218 * (0.820)	-0.3821 (0.853)
Profit motivation	0.4177 (0.464)	0.9633 (0.619)	0.1113 (0.451)	0.1122 (0.509)	-0.4417 (0.669)	0.7279 (0.842)
Risk-averse	0.6957 (0.503)	0.5451 (0.635)	1.0184 ** (0.506)	0.7122 (0.573)	1.9170 ** (0.806)	0.9448 (0.894)
Age	-0.0308 (0.022)	0.0117 (0.300)	-0.0227 (0.021)	-0.0197 (0.023)	-0.0888 ** (0.037)	-0.0536 (0.044)
Education	-0.0133 (0.510)	-0.4218 (0.680)	-0.0742 (0.464)	-0.1807 (0.527)	0.3085 (0.743)	-0.9857 (1.023)
<i>Fit Statistics</i>						
Number of observations	177		165		114	
Log likelihood	-128.90		-155.77		-64.81	
Likelihood Ratio Statistic	49.156		22.875		73.576	

Table 2.3 continued

	Corn		Wheat		Soybean	
	NT	ST	NT	ST	NT	ST
McFadden Pseudo R-squared		0.160		0.068		0.362
<u>Percentage of correct predictions</u>		71%		55%		81%
NT		74%		56%		83%
ST		50%		50%		69%
RCT		57%		42%		78%

Note: ***, ** and * indicate the estimated coefficients are significantly different from zero at the 1%, 5% and 10 % level of significance. Numbers in parenthesis represent the standard deviations of the estimates. NT=No-till, ST= Strip-till, RCT=Reduced/Conventional tillage.

Table 2.4 Marginal effects for the choice of tillage system in dryland corn, soybean and wheat

	Corn			Wheat			Soybean		
	NT	ST	CT	NT	ST	CT	NT	ST	CT
Intercept	0.4393 (0.322)	-0.2442 (0.222)	-0.1950 (0.2496)	0.0047 (0.335)	0.1092 (0.284)	-0.1139 (0.257)	-0.0242 (0.308)	0.0446 (0.235)	-0.0204 (0.174)
Rotation with corn/sorghum	---	---	---	-0.0636 (0.110)	0.0059 (0.092)	0.0577 (0.088)	0.0916 (0.092)	-0.0091 (0.072)	-0.0825 (0.052)
Rotation with legume	0.0556 (0.122)	-0.0677 (0.088)	0.0121 (0.0922)	0.1205 (0.107)	-0.1471 (0.093)	0.0266 (0.082)	---	---	---
Rotation with cereal crop	0.1151 (0.118)	-0.0666 (0.082)	-0.0485 (0.0918)	---	---	---	---	---	---
Graze crop residue	-0.0762 (0.072)	0.1208** (0.049)	-0.0446 (0.0551)	-0.0200 (0.129)	-0.0363 (0.115)	0.0563 (0.095)	0.0463 (0.104)	0.0597 (0.073)	-0.1060 (0.072)
Bale crop residue	-0.2047 (0.132)	0.0405 (0.089)	0.1642* (0.0906)	-0.1415 (0.105)	0.0698 (0.089)	0.0717 (0.078)	---	---	---
Acreage planted of crop being examined	0.0002** (0.000)	0.0000 (0.0001)	-0.0003*** (0.0001)	0.0000 (0.000)	0.0001 (0.000)	-0.0001 (0.000)	0.0005* (0.000)	-0.0002 (0.000)	-0.0004* (0.000)
Low cost producer	-0.0558 (0.100)	0.0908 (0.085)	-0.0350 (0.0651)	0.0698 (0.118)	0.0308 (0.106)	-0.1006 (0.086)	-0.1419 (0.125)	0.1886* (0.111)	-0.0467 (0.056)
On-farm income percentage	-0.0014 (0.001)	-0.0007 (0.001)	0.0022** (0.0009)	-0.0007 (0.001)	-0.0010 (0.001)	0.0017* (0.001)	-0.0007 (0.001)	0.0005 (0.001)	0.0002 (0.001)
Percentage of land rented	-0.0010 (0.001)	0.0000 (0.001)	0.0010 (0.0010)	0.0009 (0.001)	-0.0009 (0.001)	0.0000 (0.001)	0.0019 (0.001)	-0.0023** (0.001)	0.0003 (0.001)
Conservation plan	0.2182* (0.085)	-0.0795 (0.058)	-0.1387** (0.0614)	0.1045 (0.109)	-0.0020 (0.094)	-0.1025 (0.079)	0.3514** (0.142)	-0.2531** (0.112)	-0.0983 (0.076)
First time technology adopter	0.1786** (0.089)	-0.1660* (0.055)	-0.0126 (0.0700)	0.2182** (0.104)	-0.0866 (0.087)	-0.1316* (0.074)	0.2150** (0.098)	-0.1402* (0.074)	-0.0748 (0.058)
Profit motivation	-0.0051 (0.072)	0.0645 (0.052)	-0.0594 (0.0546)	0.0121 (0.086)	0.0057 (0.074)	-0.0178 (0.068)	-0.1203 (0.079)	0.0994 (0.063)	0.0209 (0.043)
Risk-averse	0.0854 (0.076)	-0.0042 (0.052)	-0.0811 (0.0587)	0.1537* (0.092)	-0.0068 (0.0797)	-0.1469* (0.075)	0.1907** (0.094)	-0.0721 (0.066)	-0.1187* (0.065)

Table 2.4 continued

	Corn			Wheat			Soybean		
	NT	ST	CT	NT	ST	CT	NT	ST	CT
Age	-0.0070 ** (0.003)	0.0040 * (0.002)	0.0030 (0.0026)	-0.0029 (0.004)	-0.0006 (0.003)	0.0035 (0.003)	-0.0080 * (0.004)	0.0025 (0.003)	0.0056 * (0.002)
Education	0.0349 (0.080)	-0.0433 (0.058)	0.0084 (0.0600)	0.0066 (0.092)	-0.0237 (0.079)	0.0171 (0.069)	0.1226 (0.092)	-0.1112 (0.074)	-0.0113 (0.048)

Note: ***, ** and * indicate the estimated coefficients are significantly different from zero at the 1%, 5% and 10 % level of significance. Numbers in parenthesis represent the standard deviations of the estimates. NT=No-till, ST= Strip-till CT= Conventional tillage.

Given the agronomic challenges to implementing continuous NT, alternating NT and tilling practices could be in the farmers' best interest in the short-term (Grandy et al., 2006; Williams et al., 2000). Grandy et al. (2006) highlight the need for active research participation to overcome agronomic and economic aspects where continuous NT may be still challenging to farmers. In addition, research and extension education programs could stress the combined effect from adopting complementary conservation practices and the importance of an integrated systems approach to ease the transition into continuous NT systems (Grandy et al., 2006).

Producers who graze their corn crop or corn residue were found to be 12.08% more likely to use ST. On the contrary, a study by Vitale et al. (2011) found that operators who graze cattle or whose main income source was from livestock were less likely to use conservation tillage, including both NT and ST practices. Grazing crop residue is a common practice among farmers to reduce livestock feed cost, but a potential problem that arises from grazed fields is soil compaction. Since tillage could be used by farmers to break the soil and eliminate soil compaction, practices such as ST that limit soil surface disturbance may be desirable for some farm operators (Hamza and Anderson, 2005). Farmers who bale their crop residue were found to be 16.4% more likely to use CT in corn production. Crop residue is usually harvested and baled either for livestock feed or bedding⁴. Conservation practices (NT and ST) require at least 30% of crop residue to remain on the soil surface, which could allow for the possibility of harvesting some residue depending on the level of crop biomass produced. However, in some cases, if crop biomass residue is limited, harvesting small volumes of crop residue can be difficult due to

⁴ An additional future potential use for crop residue is for biofuel feedstock (Banowetz et al., 2008; Berndes, Hoogwijk, and van den Broek, 2003).

equipment limitations (Perlack et al., 2005). Using CT does not impose any constraints on the amount of crop residue that can be harvested and baled. This may explain why farmers who bale their crops are more likely to use CT.

Crop acreage for the modeled crops was a significant factor in the models of tillage choice in corn and soybeans. Crop acreage was found to reduce the likelihood of using CT practices and to increase the likelihood of adopting NT. CT practices comprise several passes across fields with tillage equipment, resulting in a higher use of machinery, fuel, labor, and time. NT practices are less labor and machinery intensive than conventional practices, reducing production costs and the opportunity cost of time (Harman, et al., 1996; Pendell et al, 2007). Opting for this time-saving alternative may allow farmers to cultivate more acres (Williams et al., 2012). A study by Langemeier (2010) found that NT farms in central Kansas are generally larger than farms adopting other types of tillage practices. Another aspect that could explain a higher likelihood of adoption for larger crop acreage is that the investment in human capital and machinery per unit of land is smaller for larger farms (Epplin and Tice, 1986; Decker et al., 2009).

Results with respect to low cost producers suggested that these farmers were 18.9% more likely to use ST in soybean production. The major difference in costs between tillage systems arises from the intensity of the primary tillage practice and the number of tillage passes (Karlen et al., 2013). Thus, farm operators may see ST as a lower cost practice when compared to conventional tillage systems (i.e. from labor and fuel savings). ST has been recommended as a

good alternative to NT practices because of its economic returns and conservation benefits, especially in soils with drainage and compaction issues (Archer and Reicosky, 2009).

Results with respect to on-farm income indicated that higher on-farm income increases the likelihood of using CT by 0.22% in corn and by 0.17% in wheat production. Farmers with a larger portion of income coming from the farm operation may work less off the farm and be less time constrained to work the ground and perform tillage passes. Land tenure was not found to significantly affect tillage practice choice in corn or wheat production. Results from the soybean model suggested that a one percentage increase in the proportion of rented land reduced the likelihood of using ST by 0.23%. A study by Lee and Stewart (1983) found that the adoption of minimum tillage was lowest among operators with full land ownership. They suggested that land ownership did not pose a constraint for the adoption of minimum tillage because of the independence of tenant decisions under common leasing arrangements. In addition, they argued that this practice could be adopted by renters with the objective to reduce costs. Other studies have not found evidence of land tenure effects in the decision to adopt tillage practices (Wu and Babcock, 1998; Rahm and Huffman, 1984; and Shortle and Miranowski, 1986).

Compliance with a conservation plan through farm programs gave rise to an increase in the adoption of NT practices since 1990 (Sandretto, 2001). In this study, farmers with a conservation plan were 21.8% and 35.4% more likely to use NT practices in corn and soybean production, respectively. Farmers with a conservation plan were less likely to use CT in corn production and less likely to use ST in soybean production. Conservation is likely an important

aspect to farming for those farmers who have a conservation plan, explaining why they would be more likely to adopt NT practices.

Farmers who considered themselves first time adopters of new technologies were 17.9%, 21.8% and 21.5% more likely to adopt NT practices in corn, wheat and soybean production, respectively. These farmers who adopt new technologies before their peers were less likely to use ST or CT practices for the crops examined. Korsching et al. (1983) suggested that there is similarity between farmers who adopt innovative technologies and farmers who adopt conservation practices as both are preventive innovations. They also suggested that the adoption of soil conservation practices follows a similar pattern to the adoption of other practices, explaining why farmers who adopt new technologies (e.g. seed varieties, GPS, etc.) before other farmers may be more likely to adopt NT technologies. Results with respect to profit motivation, the variable indicating whether profit maximization was more important to the farm operator than environmental stewardship, was not significant in either model. While some farmers may adopt NT or ST practices because of the environmental benefits, other farmers' decision to adopt these practices may be driven by profit motivations (e.g. higher yields, lower costs).

Risk aversion was found to be a significant factor in explaining the choice of tillage practice in dryland soybean and wheat production. Risk-averse farmers were 19.1% and 15.4% more likely to use NT practices in dryland soybean and wheat, respectively. Risk-averse farmers were also found to be less likely to use CT in both wheat and soybean production. Previous research has identified no-plow adopters as risk-takers (Belknap and Saupe, 1988) and has catalogued risk aversion as a delaying factor in the adoption of NT practices (Krause and Black,

1995). And while other studies have also suggested that NT practices may not be an attractive practice for risk-averse farmers (Varner et al., 2011; Larson et al., 2001), this study found evidence suggesting that risk-averse farmers were more likely to adopt NT practices. Provided that farmers who perceive risk in adopting conservation practices are less likely to adopt them (Shortle and Miranowski, 1986), it is possible that a higher likelihood of NT adoption by risk-averse farmers suggest that these farmers consider NT a practice with risk-reducing potential. The increase in the adoption of conservation tillage practices and risk averse farmers' preference for NT practices could be the result of positive results experienced by early adopters and subsequent flow of information from farmer to farmer over time (Sundermeier et al., 2009; Krause and Black, 1995). In addition, the introduction of herbicide-resistant crop varieties and different herbicide options (as alternatives to fight weed pressure mechanically) have reduced some of the risk associated with NT adoption over the years (Givens et al., 2009).

Age was found to reduce the likelihood of adopting NT by 0.70% in corn and by 0.80% in soybean production. The likelihood of using CT was found to be higher (0.56%) in soybean production as age increases, in agreement with a prior expectation that older farmers may be prone to use tillage practices that are more conventional in nature. In previous literature, mixed results have been found about the effect of age on the adoption of conservation practices (See Okoye, 1998; Soule et al., 2000; Vitale et al., 2011; Warriner and Moul, 1992). Findings in the literature with respect to the effect of education on the adoption of conservation tillage practices are mixed. Some studies have found a positive effect (Shortle and Miranowski, 1986; Traoré et al., 1998; Wu and Babcock, 1998), while others have found a negative effect (Bergtold and

Molnar, 2010). In this study, college education was not a statistically significant factor in explaining tillage choice in any of the models.

2.6 Conclusions

The decision of NT, ST and CT practice was evaluated at the crop enterprise level for dryland corn, wheat and soybeans production by medium to large farmers in Kansas. The effect of farm characteristics, socio-demographic factors, risk aversion, and farmers' attitudes were evaluated. The results in this study provide additional evidence with respect to the factors affecting the adoption of conservation tillage and areas that need reinforced in farmers' education programs and when identifying target populations in designing policy incentives for conservation programs. The key findings of this study are:

- This study found evidence suggesting that farmers' crop rotation may not affect farmers' choice of tillage practice as evidenced by the statistically insignificant rotation parameters across all models. While dissemination of management information could be targeted at the crop level (e.g. dealing with crop residue and adjusting planting timing with different tillage practices), an integrated systems approach to production should be encouraged.

Particularly, the joint adoption of complementary practices (e.g. crop rotation) that could provide farmers with weed and nutrient management strategies to reduce their reliance on more conventional tillage practices. In addition, it was found that while crop-specific NT was the predominant tillage practice, continuous NT has not been widely adopted. The continuity of conservation tillage should be encouraged in order to preserve soil structure

improvements attained under NT. These soil improvements can be lost when the land is disrupted with tillage passes (Grandy et al., 2006).

- Increases in crop acreage increases the likelihood of adopting NT practices. The adoption of NT practices could be promoted among farmers who want to expand their production land under corn or wheat. Information on labor and time savings might be useful for these farmers. In addition, to encourage the adoption of NT among smaller farmers, financial aid could be provided to help farmers cover some of the start-up costs (e.g. investment in management skills and machinery).
- Baling of crop residue seems to exert a positive effect on the adoption of more conventional tillage practices. To encourage the adoption of NT practices among farmers who graze or bale their crop residue, programs could engage these farmers by providing them with soil conservation methods that would eliminate or alleviate the constraints they faced in adopting NT practices. For example, combinations of conservation tillage with other practices (e.g. cover crops, crop rotations) that could help provide needed forage and alleviate soil compaction issues.
- Farmers who are low cost producers are more likely to use ST in soybean production. Providing research-based information on cost differences between practices might entice farmers to adopt cost reducing conservation tillage practices.

- While some previous literature has suggested that NT practices may not be attractive to risk-averse farmers, this study found evidence suggesting that risk-averse farmers were more likely to adopt NT, which suggests a change in perception regarding the risk reducing benefits of NT practices. For example, well managed NT can stabilize soil structure and improve other soil characteristics, allowing for better crop resilience to mild drought risk (Dickey et al., 1989). Effectively conveying information on how NT practices could reduce risk in the long-term could be an important component to conservation programs. There is room for progress in determining how risk plays a role in farmers' adoption of conservation tillage. A study with greater focus on the role of risk could be conducted to clearly understand how specific aspects of risk (e.g. yield, returns, pest and diseases, resistant-weeds) affect farmers' decisions. In addition, an individual-specific quantitative measure of risk aversion could be included to determine how farmers' decisions are affected at different levels of risk aversion.

References

- Alberts, E.E., R.C. Wendt, and R.E. Burwell. "Corn and Soybean Cropping Effects on Soil Losses and C Factors." *Soil Science Society of America Journal* 49(1985): 721-727.
- Anaele, A.O., and U.R. Bishnoi. "Effects of Tillage, Weed-control Method and Row Spacing on Soybean yield and certain soil properties." *Soil and Tillage Research* 23(1992): 333-340.
- Archer, D.W., and D.C. Reicosky. "Economic Performance of Alternative Tillage Systems in the Northern Corn Belt." *Agronomy Journal* 101(2009):296-304.
- Banerjee, S., S.W. Martin, R.K. Roberts, J.A. Larson, R.J. Hogan Jr., J.L. Johnson, K.W. Paxton, and J.M. Reeves. "Adoption of Conservation-tillage Practices and Herbicide-resistant Seed in Cotton Production." *AgBioForum* 12(2009):258-268.
- Banowetz, G.M., A. Boateng, J.J. Steiner, S.M. Griffith, V. Sethi, and H. El-Nashaar. "Assessment of Straw Biomass Feedstock Resources in the Pacific Northwest." *Biomass and Bioenergy* 32(2008): 629-634.
- Baumgart-Getz, A., L.S. Prokopy, and K. Floress. "Why Farmers Adopt Best Management Practice in the United States: A Meta-analysis of the Adoption Literature." *Journal of Environmental Management* 96(2012):17-25.
- Baumhardt, R.L., and O.R. Jones. "Residue Management and Tillage Effects on Soil-water Storage and Grain Yield of Dryland Wheat and Sorghum for a Clay Loam in Texas." *Soil and Tillage Research* 68(2002):71-82.
- Belknap, J., and W.E. Saupe. "Farm Family Resources and the Adoption of No-Plow Tillage in Southwestern Wisconsin." *North Central Journal of Agricultural Economics* 10(1988):13-23.
- Bergtold, J.S., and J.J. Molnar. "Limited Access to Conservation: Limited- Resource Farmer Participation in the Conservation Security Program in the Southeast." *Journal of Agricultural and Applied Economics* 42(2010): 211-227.
- Berndes, G., M. Hoogwijk, and R. van den Broek. "The Contribution of Biomass in the Future Global Energy Supply: A Review of 17 Studies." *Biomass and Bioenergy* 25(2003): 1-28.
- Blanco-Canqui, H., L.R. Stone, A.J. Schlegel, D.J. Lyon, M.F. Vigil, M.M. Mikha, P.W. Stahlman, and C.W. Rice. "No-till Induced Increased in Organic Carbon Reduces Maximum Bulk Density of Soils." *Soil Science Society of America Journal* 73(2009a):1871-1879.
- Blanco-Canqui, H., M.M. Mikha, J.G. Benjamin, L.R. Stone, A.J. Schlegel, D.J. Lyon, M.F. Vigil, and P.W. Stahlman. "Regional Study of No-Till Impacts on Near-Surface Aggregate Properties that Influence Soil Erodibility." *Soil Science Society of America Journal* 73(2009b): 1361-1368.

- Blevins, R.L., D. Cook, S.H. Phillips, and R.E. Phillips. "Influence of No-till on Soil Moisture." *Agronomy Journal* 63(1971):593-596.
- Bockus, W.W., and J.P. Shroyer. "The Impact of Reduced Tillage on Soilborne Plant Pathogens." *Annual Review of Phytopathology* 36(1998): 485-500.
- Byerlee, D., and E. Hesse de Polanco. "Farmers' Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano." *American Journal of Agricultural Economics* 68(1986):519-527.
- Campbell, C.A., F. Selles, G.P. Lafond, and R.P. Zentner. "Adopting Zero Tillage Management: Impact on Soil C and N under Long-term Crop Rotations in a Thin Black Chernozem." *Canadian Journal of Soil Science* 81(2001): 139-148.
- Cooper, J.C. "A Joint Framework for Analysis of Agri-Environmental Payment Programs." *American Journal of Agricultural Economics* 85(2003):976-987.
- Coughenour, C.M. "Innovating Conservation Agriculture: The Case of No-till Cropping." *Rural Sociology* 68(2003):278-304.
- D'Emden, F.H., R.S. Llewellyn, and M.P. Burton. "Factors Influencing Adoption of Conservation Tillage in Australian Cropping Regions." *The Australian Journal of Agricultural and Resource Economics* 52(2008):169-182.
- D'Souza, G.E., D. Cyphers, and T.T. Phipps. "Factors Affecting the Adoption of Sustainable Agricultural Practices." *Agricultural and Resource Economics Review* 22(1993):159-165.
- Daniel, J.B., A.O. Abaye, M.M. Alley, C.W. Adcock, and J.C. Maitland. "Winter Annual Cover Crops in a Virginia No-till Cotton Production System: II. Cover Crop and Tillage Effects on Soil Moisture, Cotton Yield, and Cotton Quality." *The Journal of Cotton Science* 3(1999):84-91.
- Davey, K.A., and W.H. Furtan. "Factors that Affect the Adoption Decision of Conservation Tillage in the Prairie Region of Canada." *Canadian Journal of Agricultural Economics* 56(2008): 257-275.
- Decker, J., F. Epplin, D. Morley, and T. Peeper. "Economics of Five Wheat Production Systems with No-till and Conventional Tillage." *Agronomy Journal* 101(2009): 364-372.
- Dickey, E.E., D.J. Eckert, W.E. Larson, R. Johndhon, J. Mannering, J. Kinsella, I. Wikner, and R.M. Cruse. "To Till or Not to Till During Drought" *Journal of Soil and Water Conservation* 44(1989):117-120
- Ding, Y., K. Schoengold, and T. Tadesse. "The Impact of Weather Extremes on Agricultural Production Methods: Does Drought Increase Adoption of Conservation Tillage Practices?" *Journal of Agricultural and Resource Economics* 34(2009): 395-411.

- EPA - Environmental Protection Agency. "Soil preparation." (2013). Available online at: <http://www.epa.gov/oecaagct/ag101/cropsoil.html>
- Epplin, F.M., and T.F. Tice. "Influence of Crop and Farm Size on Adoption of Conservation Tillage." *Journal of Soil and Water Conservation* 41(1986): 424-427.
- Ervin, C.A., and D.E. Ervin. "Factors Affecting the Use of Soil Conservation Practices: Hypothesis, and Policy Implications." *Land Economics* 58(1982):277-292.
- Fuglie, K.O. "Conservation Tillage and Pesticide Use in the Cornbelt." *Journal of Agricultural and Applied Economics* 31(1999):133-147.
- Gaspar, A., and M. Langemeier. "Efficiency of No-Till Production in Central Kansas." Paper presented at the 2010 Risk and Profit Conference, Manhattan, KS, August (2010). Available online at: http://www.agmanager.info/events/risk_profit/2010/Papers/4_Gaspar_NoTillEfficiencyPaper.pdf
- Givens, W.A., D.R. Shaw, G.R. Kruger, W.G. Johnson, S.C. Weller, B.G. Young, R.G. Wilson, M.D.K. Owen, and D. Jordan. "Survey of Tillage Trends Following the Adoption of Glyphosate-Resistant Crops." *Weed Technology* 23(2009):150-155.
- Gould, B.W., W.E. Saupe, and R.M. Klemme. "Conservation Tillage: The Role of Farm and Operator Characteristics and the Perception of Soil Erosion." *Land Economics* 65(1989): 167-182.
- Grandy, A.S., G.P. Robertson, and K.D. Thelen. "Do Productivity and Environmental Trade-offs Justify Periodically Cultivating No-till Cropping Systems?" *Agronomy Journal* 98(2006):1377-1383.
- Greene, W.H. *Econometric Analysis*, 7th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall., 2012.
- Hamza, M.A., and W.K. Anderson. "Soil Compaction in Cropping Systems - A Review of the Nature, Causes and Possible Pollutions." *Soil and Tillage Research* 82(2005): 121-145.
- Harman, W.L., R.M. Davis, J.E. Morrison, Jr., and K.N. Potter. "Economics of Wide-bed Farming Systems for Vertisol (clay) Soils: Chisel Tillage vs. No-tillage." *Journal of American Society of Farm Managers and Rural Appraisers* 19(1996):129-134.
- Heer, W.F., and E.G. Krenzer, Jr. "Soil Water Availability for Spring Growth of Winter Wheat (*Triticum aestivum* L.) as Influenced by Early Growth and Tillage." *Soil and Tillage Research* 14(1989):185-96.
- Hensher, D.A., J.M. Rose, and W.H. Greene. *Applied Choice Analysis: A Primer*. Cambridge University Press, 2005.

- Ikerd, J.E. "The Need for a System Approach to Sustainable Agriculture." *Agriculture, Ecosystems and Environment* 46(1993): 147-160.
- Kansas State University Research and Extension, Farm Services Agency. "Soil Management - Tillage Practice Data". (2010). Available online at: <http://www.agronomy.ksu.edu/extension/p.aspx?tabid=143>
- Karlen, D.L., J.L. Kovar, C.A. Cambardella, and T.S. Colvin. "Thirty-year Tillage Effects on Crop Yield and Soil Fertility Indicators." *Soil and Tillage Research* 130(2013):24-41.
- Kaval, P. "The Profitability of Alternative Cropping Systems: a Review of the Literature." *Journal of Sustainable Agriculture* 23(2004): 47-65.
- Kladivko, E.J. "Tillage Systems and Soil Ecology." *Soil and Tillage Research* 61(2001):61-76.
- Korsching, P.F., C.W. Stofferahn, P.J. Nowak, and D.J. Wagener. "Adopter Characteristics and Adoption Patterns of Minimum Tillage: Implications for Soil Conservation Programs." *Journal of Soil and Water Conservation* 38(1983): 428-431.
- Krause, M.A., and J.R. Black. "Optimal Adoption Strategies for No-till Technology in Michigan." *Review of Agricultural Economics* 17(1995):299-310.
- Kushwaha, C.P., S.K. Tripathi, and K.P. Singh. "Soil Organic Matter and Water-stable Aggregates under Different Tillage and Residue Conditions in a Tropical Dryland Agroecosystem." *Applied Soil Ecology* 16(2001): 229-241.
- Lal, R. "Long-term Tillage and Wheel Traffic Effects on Soil Quality for Two Central Ohio soils." *Journal of Sustainable Agriculture* 14(1999):67-84.
- Langemeier, M. "Relative Technical and Cost Efficiency of No-Till Farms." *Journal of International Farm Management* 5(2010): 1-11.
- Larson, J.A., E.C. Jaenicke, R.K. Roberts, and D.D. Tyler. "Risk Effects of Alternative Winter Cover Crop, Tillage, and Nitrogen Fertilization Systems in Cotton Production." *Journal of Agricultural and Applied Economics* 33(2001):445-457.
- Lee, L.K., and W.H. Stewart. "Landownership and the Adoption of Minimum Tillage." *American Journal of Agricultural Economics* 65(1983): 256-264.
- Lichtenberg, E. "Cost-Responsiveness of Conservation Practice Adoption: A Revealed Preference Approach." *Journal of Agricultural and Resource Economics* 29(2004):420-435.
- Louviere, J.J., D.A. Hensher, and J.D. Swait. *Stated Choice Methods: Analysis and Applications*. Cambridge, NY: Cambridge University Press, 2000.
- McFadden D. *Conditional Logit Analysis on Qualitative Choice Behavior*. Frontiers of Econometrics. Zarembka, New York, 1973.

- Mueller, D.H., R.M. Klemme, and T.C. Daniel. "Short- and Long-term Cost Comparisons of Conventional and Conservation Tillage Systems in Corn Production." *Journal of Soil and Water Conservation* 40(1985):466-470.
- NASS - National Agricultural Statistics Service, USDA. "2007 Census Publication". (2007) Available online at: <http://www.agcensus.usda.gov/Publications/2007/index.php>
- Norwood, C. "Water use and yield of dryland row crops as affected by tillage." *Agronomy Journal* 91(1999):108-115.
- Okoye, C. "Comparative Analysis of Factors in the Adoption of Traditional and Recommended Soil Erosion Control Practices in Nigeria." *Soil and Tillage Research* 45(1998):251-263.
- Paustian, K., J. Six, E.T. Elliott, and H.W. Hunt. "Management Options for Reducing CO₂ Emissions from Agricultural Soils." *Biogeochemistry* 48(2000):147-163.
- Pautsch, G.R., L.A. Kurkalova, B.A. Babcock, and C.L. Kling. "The Efficiency of Sequestering Carbon in Agricultural Soils." *Contemporary Economic Policy* 19(2001):123-134.
- Pendell, D.L., J.R. Williams, S.B. Boyles, C.W. Rice, and R.G. Nelson. "Soil Carbon Sequestration Strategies with Alternative Tillage and Nitrogen Sources under Risk." *Review of Agricultural Economics* 29(2007): 247-268.
- Pereira de Herrera, A., and G. Sain. "Adoption of Maize Conservation Tillage in Azuero, Panama." CIMMYT Economics Working Paper No. 99-01. Mexico, D.F., 1999.
- Perlack, R.D., L.L. Wright, A.F. Turhollow, R.L. Graham, B.J. Stokes, and D.C. Erbach. "Biomass as Feedstock for Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply." U.S. Department of Energy and U.S. Department of Agriculture. (2005). Available online at: http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf
- Prokopy, L.S., K. Floress, D. Klotthor-Weinkauff, and A. Baumgart-Getz. "Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature." *Journal of Soil and Water Conservation* 63(2008):300-311.
- Rahm, M.R., and W.E. Huffman, "The Adoption of Reduced Tillage: The Role of Human Capital and other Variables." *American Journal of Agricultural Economics* 66(1984):405-413.
- Ribera, L.A., F.M. Hons, and J.W. Richardson. "An Economic Comparison between Conventional and No-tillage Farming Systems in Burleson County, Texas." *Agronomy Journal* 96(2004):415-424.
- Robinson, L.J., P.J. Barry, J.B. Kliebenstein, and G.F. Patrick. 1984. "Risk Attitudes: Concepts and Measurement Approaches." In: *Risk Management in Agriculture*, ed., P.J. Barry, pp. 3-30. Ames IA: Iowa State University Press.

- Sandretto, C. "Conservation tillage firmly planted in U.S. agriculture." *Agricultural Outlook*, March 2001. USDA Economic Research Service, Washington, D.C., 2001.
- Schneider, F., D. Steiger, T. Ledermann, P. Fry, and S. Rist. "No-Tillage Farming: Co-Creation of Innovation through Network Building." *Land Degradation and Development* 23(2010):242-255.
- Shortle, J.S., and J.A. Miranowski. "Effects of Risk Perceptions and Other Characteristics of Farmers and Farm Operations on the Adoption of Conservation Tillage Practices." *Applied Agricultural Research* 1(1986): 85-90.
- Sijtsma, C.H., A.J. Campbell, N.B. McLaughlin, and M.R. Carter. "Comparative Tillage Costs for Crops Rotations Utilizing Minimum Tillage on a Farm Scale." *Soil and Tillage Research* 49(1998):223-231.
- Skaggs, R.K. R.E. Kirksey, and W.M. Harper. "Determinants and Implications of Post-CRP Land Use Decisions." *Journal of Agricultural and Resource Economics* 19(1994): 299-312.
- Soule, M.J., A. Tegene, and K.D. Wiebe. "Land Tenure and the Adoption of Conservation Practices." *American Journal of Agricultural Economics* 82(2000):993-1005.
- SSSA - Soil Science Society of America. "Glossary of Soil Science Terms." (2012). Available online at <https://www.soils.org/publications/soils-glossary#>
- Sundermeier, A., L.F. Fallon Jr., H.D. Schmalzried, and L. Sundermeier. "Conservation Tillage: Repackaging the Message for Farmers." *Journal of Extension* 7(2009):1-6.
- Traoré, N., R. Landry, and N. Amara. "On-farm Adoption of Conservation Practices: The Role of Farm and Farmer Characteristics, Perceptions, and Health Hazards." *Land Economics* 74(1998):114-127.
- Uri, N.D. "Conservation Tillage and Input Use." *Environmental Geology* 29(1997):188-201.
- Varner, B.T., F.M. Epplin, and G.L. Strickland. "Economics of No-Till versus Tilled Dryland Cotton, Grain Sorghum, and Wheat." *Agronomy Journal* 103(2011): 1329-1338.
- Vitale, J.D., C. Godsey, J. Edwards, and R. Taylor. "The Adoption of Conservation Tillage Practices in Oklahoma: Findings from a Producer Survey." *Journal of Soil and Water Conservation* 66(2011):250-264.
- Wang, Y., C. Tu, L. Cheng, C. Li, L.F. Gentry, G.D. Hoyt, X. Zhang, and S. Hu. "Long-term Impact of Farming Practices on Soil Organic Carbon and Nitrogen Pools and Microbial Biomass and Activity." *Soil and Tillage Research* 117(2011): 8-16.
- Warriner, G.K., and T.M. Moul. "Kinship and Personal Communication Network Influences on the Adoption of Agriculture Conservation Technology." *Journal of Rural Studies* 8(1992):279-291.

- Welch, R., and R.Y. Rivers. "Environmental Management Strategies in Agriculture." *Agricultural and Human Values* 28(2011):297-302.
- West, T.O., and G. Marland. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." *Agriculture, Ecosystems and Environment* 91(2002):217-232.
- West, T.O., and W.M. Post. "Soil Organic Carbon Sequestration Rates for Crops with Reduced Tillage and Enhanced Rotation." *Soil Science Society of America Journal* 66(2002):1930-1946.
- Williams, J.R., M.J. Pacht, K.L. Roozeboom, R.V. Llewelyn, M.M. Claassen, and J.S. Bergtold. "Risk Analysis of Tillage and Crop Rotation Alternatives with Winter Wheat." *Journal of Agricultural and Applied Economics* 44(2012): 561-576.
- Williams, J.R., T.W. Roth, and M.M. Claassen. "Profitability of Alternative Production and Tillage Strategies for Dryland Wheat and Grain Sorghum in the Central Great Plains." *Journal of Soil and Water Conservation* 55(2000):49-56.
- Wu, J., and B.A. Babcock. "The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications." *American Journal of Agricultural Economics* 80(1998): 494-511.
- Zibilske, L.M., J.M. Bradford, and J.R. Smart. "Conservation Tillage Induced Changes in Organic Carbon, Total Nitrogen and Available Phosphorus in a Semi-arid Alkaline Subtropical Soil." *Soil and Tillage Research* 66(2002): 153-163.

Chapter 3 - Adoption of in-field conservation practices under risk

3.1 Introduction

Risk is an important component of agricultural production, and it plays an important role in farmers' production decisions, particularly decisions concerning the adoption of new conservation practices. In some cases, risk can have a larger effect than cost factors (Sattler and Nagel, 2010). The introduction and intensification of conservation on the farm introduces potential risks into the farm operation due to the introduction of new practices and their impacts on the dynamics of cropping systems, contract or practice limitations, and changes in production costs. These changes can result in shifts in net returns (due to changes in crop yields and/or costs) that may not be anticipated a priori.

When outcomes are uncertain, given their stochastic nature or their dependence on stochastic events (i.e. weather), farmers may be more hesitant to adopt a practice, requiring additional compensation to induce adoption (Kurkalova et al., 2006). Thus, risk is an important aspect that needs consideration when studying farmers' adoption decisions. However, the risk associated with stochastic variables affecting conservation adoption has not been researched in much detail, particularly in stated choice applications. In many cases, outcomes are simply assumed to happen with certainty, while in reality, farmers bear a risk of unknown changes in yields, costs and returns, as a result of adopting a particular practice or a bundle of practices, especially under contract.

Conservation-based programs that promote the adoption of conservation practices by offering financial incentives can be used to ease farmers' transition into the use of conservation practices and to reduce the risk faced by farmers from changes and variability of yields and

costs. However, withdrawal from these programs in some cases is significant (Cattaneo, 2003). To improve the environmental benefits from these programs, it is important to understand the factors that go into farmers' decision, to ensure increasing levels of adoption and the continuous maintenance of conservation practices, especially for those practices that offer significant societal benefits. With greater understanding of how farmers go about making decisions when establishing a conservation system on their farms, policymakers can better design conservation programs that are tailored to farmers' preferences, as well as limitations. Having programs that meet farmers' needs would ensure that once practices are adopted, they are not abandoned later in the process. Knowing the factors affecting farmers' adoption decisions is useful for the dissemination of informational materials in a more efficient manner, to encourage farmers to adopt and maintain sustainable production systems.

3.2 Objective

The purpose of this study is to examine farmers' willingness to adopt in-field conservation practices under risk, using a stated preference approach. Farmers' decision making for conservation practice adoption under risk was elicited using a stated choice experiment. Following Hensher, Greene, and Li (2011), a framework that accounts for the stochastic nature of net returns under a conservation contract is used. Probabilities of changes in net returns were included as an attribute in the choice experiment and were used to estimate an attribute-specific expected utility term within the random utility model, allowing for the estimation of a parameter for risk attitudes towards net returns in addition to the net return attribute parameter. Specifically, this study examines farmers' willingness to adopt in-field conservation practices under different contractual arrangements with varying levels of conservation intensity, external environmental

benefits, levels of incentive payments, and incentive payment mechanisms. Marginal willingness to accept (mWTA) values were estimated for each conservation practice, incentive program mechanisms, and off-farm environmental benefit. The mWTA estimate for each conservation practice was calculated for both non-adopters (farmers who had not adopted a particular practice at the time of the survey) and adopters (farmers who were currently using the practice at the time of the survey). To study the effect of the risk associated with net returns on farmers' willingness to adopt and intensify conservation practices, farmers' risk attitude towards changes in net returns and the risk premium for the adoption and intensification of conservation practices under a conservation contract are estimated.

3.3 Background Information

3.3.1 Conservation practice background information

Many conservation practices employed in agriculture provide benefits to the ecosystem, commonly referred to as ecosystem services. Some common ecosystem services derived from the use of in-field conservation practices are carbon sequestration, climate regulation, soil and nutrient cycling, water quality, erosion control, soil quality and productivity, groundwater recharge, pollination by wild species, biodiversity and bio-control (Robbins, 2005).

Some in-field conservation practices that provide numerous benefits to the environment and will be examined in this study are continuous no-till, conservation crop rotations, cover crops, and variable rate application (VRA) of inputs (e.g. precision agriculture). These practices were selected because they are in-field practices commonly known and adopted at different degrees in the region of study. These practices provide benefits to the environment in terms of soil carbon sequestration, erosion reduction, runoff mitigation, as well as providing potential

yield increases and reductions in production costs.

3.3.1.1 Continuous no-till

The Soil Science Society of America (SSSA, 2012) defines conservation tillage as a sequence of tillage operations that leaves at least 30% of crop cover on the surface and whose objective is to diminish the loss of soil and water. Conservation tillage practices such as no-till, strip tillage (ST) and other tillage systems leaving at least 30% of surface cover have proven to be beneficial for the soil. In no-till systems, soil disturbance is limited to nutrient injection. Plant residue is left on the soil surface and only partial removal is allowed. No-till practices leave the greatest level of crop residue on the soil surface. Different from rotational no-till, in continuous no-till, all the crops in the rotation are planted using a no-till drill/planter and no-till equipment is used year round.

Some of the benefits associated with conservation tillage systems are an increase in soil organic carbon, soil microbial biomass, reduction of wind and water soil erosion, and enhancement of nutrient cycling (Blanco-Canqui et al., 2009; Campbell et al., 2001; Kladivko, 2001; Kushwaha et al., 2001; Lal, 1999; Paustian et al., 2000; Wang et al., 2011; Zibilske et al., 2002). Another advantage associated with no-till is the preservation of soil moisture (Blevins et al., 1983; Daniel et al., 1999), which may allow farmers to increase production intensity in dryer areas. While benefits can still be obtained when using rotational tillage, when no-till soils are disrupted with tillage, some of the soil benefits obtained while in no-till are lost, especially soil organic carbon and improvements to soil structure (Grandy et al., 2006).

Along with the positive aspects attributed to conservation tillage, some negative effects have also been reported in the literature. A potential drawback from NT practices is the delay in

planting due to slower soil warming (DeJong-Hughes and Vetsch, 2007). In addition, large accumulations of crop and/or cover crop residue on the surface of no-till fields could obstruct other activities, such as planting, due to residue plugging up equipment. In some regions, moisture retention by crop residue left on the surface could increase the incidence of diseases (Anaele and Bishnoi, 1992; Bockus and Shroyer, 1998) and possibly result in lower yields (Heer and Krenzer Jr, 1989). The need to chemically control weeds and the increase in diseases could result in higher chemical costs that in some cases could offset the savings in labor and machinery (Williams et al., 2000).

Overall, no-till practices have shown to be a great option for the improvement of soil health and to increase carbon sequestration (West and Marland, 2002; West and Post, 2002). No-till practices may result in lower fuel and machinery labor expenses due to a lower number of field passes (Epplin et al., 1982). This may allow for an increase in cropping intensity (Williams et al., 2012). The base cost associated with implementing no-till in Kansas is estimated at \$19.8 per acre by the NRCS (2015b). A comparison of studies in the literature suggested that no-till systems are the least costly when compared to conventional systems (Kaval, 2004). Regarding yield risk, while some studies agree that no-till practices reduce risk (Ribera et al., 2004; Williams et al., 2000), other studies suggest that no-till increases risk (Larson et al., 2001a; Varner et al., 2011). In order to improve the benefits associated with no-till practices, other conservation methods such as cover crops and crop rotation are encouraged.

3.3.1.2 Conservation crop rotation

Crop rotation consists of rotating different unrelated crops within the same field in a predetermined sequence. A conservation crop rotation would include green manures, perennial

grasses, heavy residue cash crops and reduction of fallow periods (NRCS, 2015b). Some benefits associated with crop rotation are the mitigation of diseases, pests, and weeds that accumulate from continuous cropping of the same taxonomic crop families. Other benefits are the carryover of residual herbicide and reduction of allelopathic or phytotoxic effects (Lodhi et al., 1987; Pierce and Rice, 1988; Roth, 1996).

Fertility of the soil can be improved by avoiding depletion of common nutrients required by particular crops, using nitrogen fixing crops such as legumes (Zotarelli et al., 2012) or other crops that can introduce necessary elements back into the soil. The use of high residue crops (i.e. wheat, sorghum) and legumes in the rotation have the potential to increase carbon and nitrogen concentration in the soil over the long-term (Kelley et al., 2003; Miglierina et al., 2012). Additionally, improvements in soil structure arise when deep and shallow rooted crops are used in the crop rotation. The increase in soil aggregate stability and improvements in water utilization are further results from the use of crop rotations (Chan and Heenan, 1996; Raimbault and Vyn, 1991).

Lastly, continuous crop rotation or increasing the number of crops in a rotation could increase carbon sequestration (West and Post, 2002). The benefits mentioned above could result in an improvement in soil health and soil productivity. Additionally, studies have demonstrated yield advantages from crop rotation, reductions in yield variability (Helmets et al., 1986); and income diversification. The cost associated with a conservation crop rotation as estimated by the NRCS (2015b) is \$14.0 per acre. Studies in the literature have stressed the importance of the joint use of crop rotation and other conservation practices. For example, the combination of crop rotation and no-till practices are important for weed control, soil carbon sequestration, and to increase nutrients in the soil (Cardina et al., 2009; Havlin et al., 1990; McConkey et al., 2003).

3.3.1.3 Cover crops

Use of cover crops as a conservation practice consists of growing seasonal crop varieties between annual cash crops. The objective of the cover crop is to provide protection of the soil surface from soil and water erosion. Cover crops may be a cost-efficient alternative for improving crop nutrient management, while also providing additional conservation benefits. Additional benefits associated with the use of cover crops are the reduction of wind, water and soil erosion; weed suppression; conservation of soil moisture; improvement in soil structure and the levels of organic matter; and the provision of habitats for beneficial organisms (Snapp et al., 2005).

Some cover crops contribute to the addition of nitrogen into the soil while other crops are good nutrient scavengers. Grain, grasses and perennial legumes contribute to production of soil organic carbon. Legume cover crops are more effective at increasing cash crop yields compared to other cover crops (Miguez and Bollero, 2005). Cover crops in combination with no-till systems may provide significant benefits to the soil through increases in soil carbon sequestration and nitrogen concentrations (Nascente et al., 2013). Reicosky and Forcella (1998) stressed the importance of cover crops in conjunction with conservation tillage to maximize additions to soil carbon. For a comprehensive review of the use of cover crops varieties in conjunction with other conservation practices such as conservation tillage and crop rotations, see Clark (2008).

Using cover crops can be costly and users face economic and operational constraints (Sarrantonio and Gallandt, 2003). The main cost in establishing a cover crop is the seed cost (for seed varieties, planting rates and costs see Clark (2008). Cost estimates by the NRCS (2015b) for annual grass or legume covers are around \$82 per acre. Cover crops could result in higher yields and reduce production risk (Jaenicke et al., 2003). However, this may not always be the

case. The benefits obtained in some cases may not compensate for the cost of establishing the cover crop (Larson et al., 2001b) and higher profits may not always be obtained (Lu et al., 2000). Some of the benefits of cover crops may not be realized in the first years during adoption and in many cases they may be difficult to quantify monetarily (Clark, 2008).

3.3.1.4 VRA of inputs

Variable-rate application of inputs consists of spatially varying input rates based on field requirements with the aid of computer-controlled devices. The objective of the VRA of inputs is to maximize the economic efficiency of input application. For example, fertilizer applications can be managed to increase fertilization in zones with high soil productivity and reduce fertilization in areas with low productivity.

It has been argued that the primary cause of fertilizer pollution stems from the inefficiency in its use (Khanna and Zilberman 1997). It is estimated that leaching of residual nitrogen in major field crops ranges from 10 to 35 percent (Meisinger et al., 2008). VRA of fertilizer technology increases the efficiency of input application, reducing runoff and leaching of nutrients (Khanna and Zilberman, 1997), improving surface and ground water quality. This technology may increase output quantity and quality and reduce input cost, leading to an increase in profitability (Vellidis et al., 2013). The use of positioning systems also reduces the repetition of machinery passes over the same area, reducing labor costs (Adrian et al., 2005).

The adoption of VRA technologies may require a large investment in new equipment and an in human capital to develop the necessary skills and knowledge that are required to operate successfully (Batte and Arnholt, 2003). Equipment cost for precision fertilizer application is estimated around \$11.30 per acre; however additional cost may be incurred, like

the use of special skilled labor and soil/tissue testing (NRCS, 2015a). The high cost of VRA technologies may lead to the use of custom applications by third parties in some areas. Although this technology may increase yields and reduce input cost, profitability is site-specific and varies according to the characteristics of the field (Roberts et al., 2000). In many cases however, the benefits may not be significant (Biermacher et al., 2009). The uncertainty about the benefits from this practice has been a factor slowing its adoption (Schimmelpfennig and Ebel, 2011). This technology results in additional environmental benefits to those provided by no-till, cover crops and dynamic crop rotations by reducing the risk of agro-chemical related pollution.

3.3.2 Payment mechanisms and conservation programs

In the last few decades, much attention has been given to environmental degradation and to the ways in which sustainable production can be achieved in agricultural systems. Environmental degradation is defined as any disturbance to the environment that can deteriorate soil, water, and/or air resources (Johnson et al., 1997). Some agricultural activities such as soil mechanization and the application of agrochemicals can result in soil erosion, pollution of water bodies, and greenhouse gas emissions (Aneja et al., 2009; Carpenter et al., 1998; Galloway et al., 2008; Kim and Dale, 2008; Lal, 1993).

The ecosystem services produced when conservation practices are in place have a value to society, and by creating a market for these services, farmers could receive an incentive to adopt conservation practices (Ribaud et al., 2010; Whitten and Coggan, 2013). While it has been argued that market-based instruments may be more efficient to encourage conservation (Freeman and Kolstad, 2006), to date, the U.S. government has primarily relied on cash

payments through voluntary contractual programs for the adoption of conservation practices (Claassen et al., 2008).

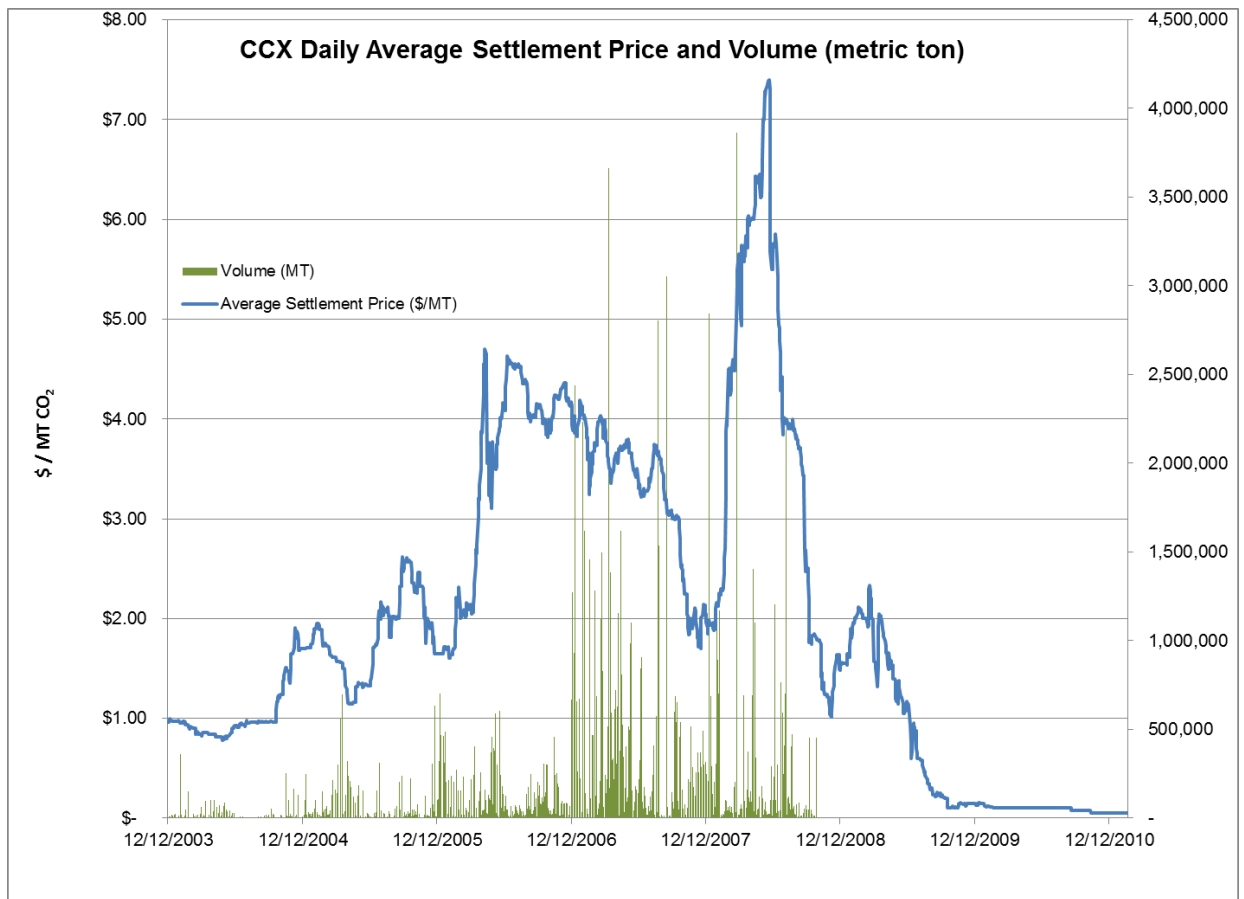
Conservation-based programs that promote the adoption of conservation practices by offering financial incentives are in place in the United States (U.S.). These programs are used to ease farmers' transition into the use of conservation practices and to reduce the risk faced by farmers from changes and variability of yields and costs. The Natural Resource Conservation Service (NRCS) administers voluntary federal conservation programs such as the Environmental Quality Incentive Programs (EQIP) and the Conservation Stewardship Program (CSP), which have the main objective of promoting the adoption of structural or in-field conservation practices in agricultural and forest land to meet environmental conservation goals (NRCS, 2013). These programs primarily focus on water quality and conservation; soil conservation; land preservation; wildlife habitat; air quality; and energy conservation (Claassen et al., 2008).

In some cases, the limited knowledge farmers have about the availability of conservation incentive programs, how they work, and the complexity of the programs may deter farmers from participating (Brewer et al., 2004; Reimer and Prokopy, 2014). In other instances, some of the practices in the contracts are never implemented or practices are withdrawn from already signed contracts (Cattaneo, 2003). A study by Cattaneo (2003) revealed that 11% of the practices in EQIP contracts are never implemented, 17% of the contracts are partially withdrawn, and 6% are completely withdrawn. The author attributed those results to the fact that practices may be seem attractive when farmers submit their proposals, while in practice, these conservation practices do not provide sufficient private benefits. Withdrawals from EQIP contracts were also found to be more likely to occur during the first years of implementation.

An alternative approach to encourage conservation adoption is the use of market-based instruments. For example, given the greenhouse gasses (GHG) emissions mitigation potential of agriculture (Smith et al., 2008), market-based mechanisms have been developed in order to meet GHG reduction targets (Williams et al., 2009). An example of such a mechanism is carbon offsets issued through a carbon sequestration program that compensates landowners for the adoption of conservation practices that improve soil carbon sequestration and/or reduce carbon emissions (Williams et al., 2009). Under this mechanism, carbon offset credits are traded in a carbon exchange where companies who have emitted GHG above their target can buy carbon credits from sellers who are committed to provide carbon offsets from carbon sequestration efforts (Williams et al., 2009). For a comprehensive review of carbon offsets from agriculture refer to Williams et al. (2009) and González-Ramírez, Kling, and Valcu (2012).

In the U.S., carbon trading has mainly taken place under a voluntary cap and trade platform, the Chicago Climate Exchange (CCX) that operated from 2003 to 2010 (Hamilton et al., 2009). However, in 2008 less than 1% of the carbon offset credits traded came from agricultural soils, where participating farmers were compensated per ton of carbon sequestered (Hamilton et al., 2009). Under this program, farmers did not directly trade their credits, but various offset aggregators served as trading representatives. Some of the offset aggregators were the National Carbon Offset Coalition (NCOC) in Montana; AgraGate, a subsidiary of the Iowa Farm Bureau; North Dakota's Farmers Union; and the Environmental Carbon Credit Pool, LLC. The CCX closed in 2010 when carbon prices fell to 0.10-0.15 \$/ton CO₂ (See Figure 3.1).

Figure 3.1 Chicago Climate Exchange, historical price and volume traded



Source: Chicago Climate Exchange. Available at: <https://www.theice.com/ccx>

Another market-based carbon trading mechanism is “over the counter retail markets”, which are voluntary programs where consumers pay for activities to help reduce their carbon footprint (Ribaud et al., 2010). An example of a well established carbon market was the European Union where a mandatory market was developed under the Kyoto Protocol’s Clean Development Mechanism (Galatowitsch, 2009; Williams et al., 2009). In the U.S., there was an unsuccessful attempt to pass a policy, the Clean and Energy Security Act of 2009 (i.e. H.R. 2454), to regulate carbon emissions (Golden et al., 2009). The development of a carbon market has proved difficult without a binding GHG policy (Young, 2003). However, while carbon trading schemes and efforts to implement a cap-and-trade policy to regulate GHG emissions have not been successful in the U.S. (i.e. H.R. 2454), it is likely that efforts to pass a comprehensive policy will reappear in the future (González-Ramírez et al., 2012). Currently, the Environmental Protection Agency (EPA) has proposed rules to regulate GHG emissions. While the regulatory mechanisms proposed by the EPA do not use market-based instruments, discussions around the lower cost of market-based mechanisms have surfaced (Kotchen and Mansur, 2014). Thus, it is important to understand farmers’ preference for this mechanism as carbon markets could potentially develop again in the future.

Currently, the level of adoption (including the level of voluntary adoption under conservation contracts), is low for some conservation practices. The National Crop Residue Management Survey showed that 21% of corn acreage, 39.3% of soybeans, 19.6% of sorghum, and 14-16% of small grains were managed under no-till (NT) by 2008 (CTIC, 2013). This survey also found that conventional tillage (CT) and reduced tillage (RT) still accounted for approximately 58% of the cultivated land (CTIC, 2013). A survey looking at the adoption of cover crops in the Corn Belt found that only 18% of the farmers had planted cover crops. They

also found that adopters had used cover crops on only about 6% of their land (Singer et al., 2007). Evidence found in the Agricultural Resource Management Survey also suggests that variable rate technologies have been adopted at a low rate of 8 to 14% between 2005-2009 (Schimmelpfennig and Ebel, 2011). Considering the conservation benefits and carbon sequestration potential these practices provide, current adoption rates might not be socially optimal. Farmers' adoption decisions are mainly based on economic motives (Cooper, 2003), and in many cases economic incentives deter conservation on the farm (Antle and Diagana, 2003). As Ribaud et al. (2010) notes, if payments for environmental services do not reflect their value to society, given market price signals, farmers produce less environmental services than socially optimal. In addition, lack of knowledge of the social benefits may also contribute to sub-optimal adoption levels (Kurkalova et al., 2006). As evidence in the literature suggests, off-farm environmental benefits are also important drivers for the adoption of conservation practices in agriculture (Reimer and Prokopy, 2014).

The lack of knowledge about the benefits from conservation practices, lack of infrastructure, lack of support, practice incompatibility, and financial support are some of the potential constraints for the adoption of conservation practices (Rodriguez et al., 2009). Additionally, subsidy programs for certain agricultural commodities may have discouraged sustainable practices, causing slower rates of adoption (Derpsch et al., 2010). For example, subsidies to agricultural inputs and subsidies to corn-ethanol production, which have also resulted in higher commodity prices, may have indirectly resulted in the intensification of agricultural production and the removal of land from conservation retirement programs (Comito et al., 2013; Gill-Austern, 2011). There is also evidence suggesting that higher commodity prices

have encouraged some producers to have less diversified rotations on their farms (Fargione et al., 2009; Tyner and Taheripour, 2008).

3.4 Literature Review

3.4.1 Conservation practices adoption

In recent years, great attention has been placed on the use of conservation systems in agricultural production. While the literature has presented evidence indicating that conservation practices offer a great alternative for enhancing soil and water resources, conventional systems still remain the prevailing norm in many regions.

A large and growing body of literature has investigated factors affecting the adoption of conservation practices. Studies looking at the factors influencing the adoption of conservation practices date back to the 1950s (Ervin and Ervin, 1982). These studies have used different econometric models and sets of explanatory variables. Several of these studies have used revealed preference data and fewer have used stated preference methods.

Early work in the adoption literature examined the adoption of single practices, often modeled as a discrete choice using univariate logit or probit models. Many of these studies examined the adoption of reduced/conservation tillage practices (Belknap and Saupe, 1988; Davey and Furtan, 2008; Rahm and Huffman, 1984; Soule et al., 2000). Other studies examined the adoption of newly introduced production technologies. Shapiro, Wade Brorsen, and Doster (1992) studied the adoption and the extent of adoption of double-cropping soybeans and wheat. Other studies evaluated the adoption of intensive sustainable and low input agricultural practices among farmers in Montana (Saltiel et al., 1994); the adoption of precision agriculture; and the adoption of genetically modified corn and soybean crops (Fernandez-Cornejo et al., 2002). Other

studies have also examined the adoption of best management practices (BMP) in agricultural production. Kim, Gillespie, and Paudel (2005) studied the adoption of BMP (cover and green manure crops, critical area planting, filter border/filter strips, grassed waterways, heavy use area protection, livestock exclusion, regulating water, riparian forest buffer) in beef cattle production using probit models. They found that risk negatively affects the adoption of rotational grazing and cover crops in beef cattle production.

There are a myriad of conservation practices farmers can implement on their cropland, and the adoption of a particular practice may not be independent or isolated from the decision to adopt other practices. In some instances, examining the adoption of an individual practice may delay the complex decision farmers' face. Several studies have attempted to analyze the adoption of multiple practices using multinomial logit models (Caswell and Zilberman, 1985; Fuglie, 1999). Caswell and Zilberman (1985) studied the factors affecting the adoption of drip, sprinkler, and surface irrigation by fruit growers in California. The adoption of drip and sprinklers was compared against traditional surface irrigation. A study by Fuglie (1999) examined the adoption decision for tillage practices (CT, NT, RT or conservation tillage) in corn production using data from a survey conducted by the USDA.

The joint adoption of conservation practices has also been examined using multinomial logit models. Wu and Babcock (1998) conducted a joint analysis of the choice to adopt conservation tillage, crop rotation and soil testing in Central Nebraska using a multinomial logit. Another study looking at the choice of conservation practices in a joint framework is Bergtold and Molnar (2010) who examined factors affecting the adoption of conservation tillage, crop rotation and soil testing by small limited-resource farmers in the Southeast. While using a multinomial logit model allows examining joint adoption, in many cases the independence from

irrelevant alternatives (IIA) property of the model could be very restrictive in modeling the correlation between bundle of practices (Maddala, 1983).

In order to model the correlation among the practices adopted by producers, Dorfman (1996) proposed a multivariate adoption model. His study modeled the adoption of integrated pest management (IPM) and improved irrigation using a multinomial probit model. Dorfman's approach allowed for the modeling of interrelationships among conservation practice adoption choices, represented as the nonzero correlation among the errors from a system of adoption equations. Lichtenberg (2004) modeled the adoption decision of seven on-farm conservation practices (critical area seeding, contour farming, strip-cropping, cover crops, grass, terraces, and diversions) by farmers in Maryland. His study found evidence of cost responsiveness in the adoption decision and complementarity among some of the conservation practices considered.

The previous studies mentioned all used revealed preference methods with observed choices. Stated choice methods have also been widely used to study adoption decisions as they provide some additional advantages. Stated choice methods allow for the examination of attributes that are not present in the market, or if they are present, do not have sufficient variation to estimate their parameters (Louviere et al., 2000). For example, the use of stated choice methods has allowed researchers to study the effect of varying incentive payments/cost-share levels on the adoption and extent of adoption of conservation practices and programs. The use of stated choice methods have also furthered the study of other attributes in conservation programs that are of interest for policy makers. Some of these attributes are contract length, risk attributes, payment mechanisms, availability of technical assistance or insurance through a conservation program, restrictions on land use, and contract default (Cooper, 2003; Cooper and Signorello, 2008; Espinosa-Goded et al., 2010; Ma et al., 2012; Ruto and Garrod, 2009).

Some examples of studies eliciting the adoption of conservation practices using stated choice methods are Cooper and Keim (1996), Cooper (2003), Cooper and Signorello (2008), and Ma et al. (2012). Cooper and Keim (1996) studied farmers' adoption of five EQIP practices (integrated pest management (IPM), legume crediting, manure testing, split applications of nitrogen, and soil moisture testing) using a dichotomous choice contingent valuation approach to elicit farmers' WTA. They modeled the decision to adopt and the potential level of adoption (acres) given the incentives offered, by farmers not currently using the practice. In their study, the adoption for each of the practices was modeled independently.

A study by Cooper (2003) examined the adoption of five conservation practices (conservation tillage, IPM, legume crediting, manure testing, soil moisture testing) in a joint framework. In their study, farmers were presented with hypothetical cost shares for adopting each practice individually, and the decision to adopt was modeled jointly using a multinomial probit to account for the correlation among conservation practice adoption choices through the errors in the latent adoption equations. In another study, Cooper and Signorello (2008) examined the adoption and risk premium for the adoption of a conservation protocol that included crop rotation, soil tillage, organic fertilizer, and mechanized weeding with data collected using a multiple-bounded format for the willingness to accept adoption question.

In a study conducted by Ma et al. (2012) individuals were presented with four systems with bundle of practices with increasing level of intensity. The attributes examined in their study were payment, payment provider (government or a non-governmental organization), and sequence of conservation intensity (environmental benefit) in which the four systems were presented (increasing or decreasing). For each of the four systems, the authors modeled the willingness-to-consider decision using a probit model, and the acreage enrollment decision using

a tobit model.

3.4.2 Risk in the adoption literature

Various sources of risk affect agriculture (Beal, 1996). Studies in the literature have provided evidence of the importance of risk in agricultural decisions (Marra and Carlson, 1990) and it has been long argued that risk represents an obstacle in the adoption of new agricultural practices (Aimin, 2010). In some instances, risk factors may be more important than other production factors (Sattler and Nagel, 2010). While risk is central to the study of farmers' decisions to adopt agricultural technologies, studies addressing risk in context of adoption have been limited (Marra et al., 2003).

Marra, Pannell, and Abadi Ghadim (2003) identified distinctive elements of risk that affect the adoption of new agricultural technologies, namely, perception of the probabilities of the distribution of net returns, the variance of net returns, and the strength and direction of risk attitudes (i.e. risk aversion). Measuring risk aversion without adequate data can be difficult. Researchers have used different strategies to measure the impact of risk on the adoption decision.

Some studies examining adoption in the literature (both, with revealed and stated preference data) have included risk aversion as a dummy variable indicating whether the farm operator is perceived to be risk-averse (Kim et al., 2005; Shapiro et al., 1992). Shapiro et al. (1992) evaluated both the effect of risk attitudes and farmers' subjective perceptions of risk on the adoption of double crop soybeans. However, while they estimated farmers' Pratt-Arrow measures of risk aversion, in their empirical model they used dummy variables indicating if farmers were risk averse (they used the midpoint of the range of risk aversion as the dividing

point). Kim, Gillespie, and Paudel (2005) examined the adoption of BMPs in beef cattle production using probit models. In their study, they included farmers' self-identified risk preference as a dummy variable indicating if the farmer was risk averse. Both studies found that risk aversion was an important factor affecting adoption.

Other studies have included a risk aversion coefficient (i.e. Pratt-Arrow measure of risk aversion) when modeling adoption. Ghadim, Pannell, and Burton (2005) examined adoption of chickpeas in Australia using a probit and tobit model. They examined the effect of farmers' risk preferences (Pratt-Arrow risk aversion coefficient); the perception of riskiness of chickpeas production; an interactions between the risk aversion coefficient and area (hectares); relative riskiness of chickpea production; and perceived variance of the net revenue from chickpea production. They found that both risk aversion and riskiness of the practice, reduced adoption of chickpeas and underweighted the benefits from farm diversification from undertaking this crop enterprise on the farm.

In studies examining the adoption of conservation systems under conservation incentive programs, the incentive payment always plays an important role on farmers' willingness to adopt. Since introducing new practices on the farm may result in changes in net returns, farmers may demand a higher incentive payment to offset any risks from adoption. For example, risk-averse operators may require a risk premium to induce their adoption of new practices, even if they obtain higher income as a result of their decision to adopt (Kurkalova et al., 2006). The existence of this risk premium may result in higher WTA estimates. A study by Cooper and Signorello (2008) expanded on previous literature about conservation adoption by proposing a theoretical model that included a risk premium component, as a function of the variance of profits from adopting a new practice, within a random utility framework. To estimate their

model empirically, the proposed risk component was estimated as the difference between the mean WTA and the difference in profits from the base state and the adoption state. While additional information on changes in profits is required to estimate the risk premium, farmers were not provided with this information during the decision process. Thus, there may be asymmetry of profit information across farmers, impacting results.

Several of the studies examining the effect of risk (e.g. risk preference) in adoption models have done so under a deterministic framework. Few have considered the stochastic nature of the adoption process (i.e. Ghadim, Pannell, and Burton, 2005). While the distinctive elements of risk identified by Marra, Pannell, and Ghadim (2003), have been partially or separately addressed in some studies, they have not been extensively studied, particularly in stated choice frameworks.

3.4.3 Uncertainty and risk attitudes in stated preference methods

In many cases, individuals are subject to decisions for which outcomes are not known with certainty, they are stochastic in nature. However, when studying decisions using stated choice frameworks, in most cases individuals are asked to choose between alternative options in a deterministic environment. Recent studies have attempted to study decisions under risk by introducing stochastic attributes in stated choice studies. In these studies, the probability distribution of potential attribute outcomes is provided explicitly in the stated choice tasks.

One approach to model risk is to introduce the probability of occurrence of the attribute in an additive form. That is, the outcome attribute and the risk (i.e. the probability of the attribute outcome) are treated as two separate attributes and a utility parameter is estimated for each one of them individually. A study by Glenk and Colombo (2011) followed such an approach. In their

study of public preferences for a climate change mitigation program, they assessed the introduction of risk associated with the program's potential to achieve emission reductions. In their study, individuals were first presented with a set of choices with no risk. If they chose the program at least once, then they were presented with a second set of choices which provided information on both the percentage of annual emission reductions from a soil carbon sequestration program and the probability that the program fails to achieve that level of emissions reduction. They estimated three models: (1) no-risk, (2) risk (probability) was modeled as being continuous, and (3) risk (probability) was modeled as being discrete. They found that while risk did not affect the WTP estimates for the non-stochastic attributes, it did affect respondents' preference for the program. They also found a larger WTP for a higher risk of program failure.

In a study of the WTP for a program to reduce the risk of wastewater floods in Switzerland, Veronesi et al. (2014) examined the effect of risk by including an attribute with the frequency of flooding events and a forecast confidence attribute consisting of probabilities that the forecast was correct. They found that uncertainty (probability) of the forecast was not a statistical significant factor and was found to be the least important factor in individuals' preference for the abatement program. The authors attributed this result to the respondents' using heuristics to evaluate the probability of forecast occurrence.

Another approach used by some researchers consisted of estimating the effect of the stochastic attribute, and the effect of an interaction term between the attribute and its probability of occurrence (this mirrors the expected value or the use of a linear utility function for the expected utility model). Burghart, Cameron, and Gerdes (2007) studied peoples' preference for a program to invest in energy saving air-conditioning technologies funded with tax credits. They

examined the risk that the technology would be successful. Individuals were asked if they were willing to invest their tax credits in the development of energy saving technologies that would save them money in the future, but with caveat that there was a probability (risk) that these technologies would fail. They modeled risk using a linear discounted expected random utility framework.

In a study of preferences for water quality in lakes, Roberts, Boyer, and Lusk (2008) included the risk associated with two attributes, an algae bloom and changes in water level. They presented risk as the probability of occurrence of the algae bloom and the probability to observe a given water level. They introduced aspects of prospect theory by using probability weights. Respondents were asked to complete stated choice tasks with either certain outcomes or risky outcomes. They modeled risk in a multiplicative fashion, by multiplying the probability of occurrence by the attribute outcome (expected value), and estimated a model coefficient for the expected value of the attribute (algae bloom and each of the water levels). They found higher WTP estimates in the presence of risk. They also found that a model using probability weights, instead of linear weights provided a better statistical fit.

Akter, Bennett, and Ward (2012) studied public support for a climate change mitigation plan. The choice experiment presented choice alternatives varying by cost (higher household cost from higher electricity bills, fuel, etc.), expected rise in temperature, and its probability of occurrence. They estimated a parameter for the probability of a rise in temperature and another parameter for the interaction of the rise in temperature and its probability of occurrence (expected increase in temperature). They found greater support for the plan with greater probability of temperature rises.

A study by Rolfe and Windle (2013) analyzed different management programs for coral reefs. They introduced risk in their study by providing decision makers with the percentage of coral reef protected in good condition under each management mechanism conditional on the probability that this level of protection will be obtained. They modeled the choices using a mixed logit model where the condition of the reef, and an interaction term between reef condition and probability of protection were included in the model.

While using the expected value of the stochastic attribute to model choices under risk allows a modeler to capture how respondents' preferences are affected when faced with uncertain outcomes, it assumes risk neutrality (preferences for the risky attribute are assumed to be linear). In order to allow for risk aversion/risk seeking behavior in decision making under risk, some stated choice studies (mainly in the transportation literature) have incorporated risk and uncertainty into choice decisions by introducing aspects of expected utility theory and prospect theory into the random utility decision framework. This approach allows for the estimation of a decision-maker's risk attitude toward the stochastic attribute in addition to the marginal utility (parameter) for the stochastic attribute (Hensher et al., 2011).

Hensher, Greene, and Li (2011) and Li et al. (2012) studied the risk associated with time variability in a scheduling model for car commuters using a choice experiment. Commuters were presented with a distribution of departure times with an associated probability of occurrence. The time attribute was incorporated in the random utility function using a general power specification, which exhibits constant relative risk aversion. Probabilities were transformed using separable probability weighting functions. That is, the probability transformation is independent of the outcomes (dependent only on the original probabilities). Other deterministic attributes were included in the random utility in a linear form. They found that the risk-based model

predicted optimal departure times better than a purely linear functional form where decision-makers are assumed risk neutral. They also found evidence suggesting that commuters exhibited, in general, risk-taking attitudes.

Other studies have modeled risk within the random utility framework using a non-expected utility approach, which transforms probabilities of occurrence of an event using weighting functions. Probability weights are used as evidence in the literature suggests, individuals transform absolute probabilities into decision weights using heuristics (Kahneman and Tversky, 1979). Van Houtven et al. (2011) studied disease treatment preference in the presence of mortality risks. They estimated three model specifications with varying treatments for risk: (1) a categorical model for risk (dummy variables for the probabilities of each risk were used), (2) independent weighing functions, and (3) rank dependent utility where probability weights depend of both the original probability and the outcome. They found evidence that supports the use of probability weights and rank dependent utility models. A study by Wibbenmeyer et al. (2013) examined wildfire managers' preferences for fire suppression strategies under two sources of risk: probability that the fire reaches homes or watershed in the absence of a suppression strategy, and the probability of success of the suppression strategy. They found larger responses to risk for lower probabilities in proportion to the response observed with greater probabilities. They also found that the risk of houses burning had a greater effect among managers than the risk of watersheds burning.

Using data from a stated choice experiment examining people's preferences for a soil carbon sequestration program, Glenk and Colombo (2013) tested different model specifications for the treatment of risk within the random utility model using combinations of: linear expected utility functions of emission reductions (expected value); non-linear expected utility functions,

linear probability weights (probability to achieve the emission reductions); non-linear probability weights; and inclusion of a separate disutility parameter for risk (i.e. probability of failure to achieve reduction levels) (Glenk and Colombo, 2011). Their results suggest that significant differences in WTP estimates can be obtained when using different model specifications, as each model revealed different behavioral assumptions. They recommend using models with a non-linear specification for the expected utility component.

Li and Hensher (2013) extended the above studies by embedding a ranked dependent expected utility model within a random utility framework, in which the probability weighting functions are determined by both, the original probabilities and the rank of the outcomes in terms of preference. In addition to revealing preferences and risk attitudes (like in Hensher, Greene, and Li, 2011; and Li, Tirachini, and Hensher, 2012), this approach reveals beliefs by differentiating how decision makers transform probabilities for preferred and least preferred outcomes. They found that commuters, in general, underweighted the probability of arriving on-time, implying conservative beliefs.

3.4.4 Summary

Research has consistently pointed to the importance of risk in decision making. However, studies on the subject of conservation adoption have been mostly restricted to the effect of risk attitudes in the adoption of conservation. Few studies have addressed the stochastic nature of the factors involved in the adoption process. This study expands on previous research by examining conservation program attributes that have not been widely evaluated in the conservation adoption literature to-date, such as farmers' risk attitudes and adoption decisions under risk, and preferences for conservation payment mechanisms through government

programs or market-based mechanisms. This study also examines if the environmental benefits obtained off the farm from the adoption of conservation practices is an important factor in the farmer's decision to adopt conservation practices on the farm. Results from this study provide an understanding of farmers' decision process when adopting conservation practices and conservation program participation. The identification of motivations, as well as obstacles in the adoption of conservation practices is a fundamental necessity for improving conservation policies and programs.

3.5 Methods

3.5.1 *Random utility framework*

Individuals' choice decisions in stated preference models are constructed on the basis that individuals derive utility from product attributes - Lancaster's theory (Lancaster, 1966). In this study, farmer i derives utility from choosing conservation contract j with a given set of attributes X_j . Now, let π_{iq} be farmer i 's expected net return in the *status quo* and π_{ij} be net returns (excluding any incentive payment) under a conservation contract for farmer i . Since there is uncertainty concerning the value of net returns, particularly under a conservation contract, π_{iq} and π_{ij} are stochastic in nature with associated variances given by $\sigma_{\pi_q}^2$ and $\sigma_{\pi_j}^2$, respectively. Now let the i^{th} farmer's utility (U_{ij}) from signing a conservation contract be a function of the contract attributes (X_{ij}), and the stochastic net returns $\pi_{ij}(\sigma_{\pi_j}^2)$. That is, farmers receive utility from contract j : $U_{ij} = V_{ij}[X_{ij}, F(\pi_{ij}(\sigma_{\pi_j}^2))] + \varepsilon_{i1}$, where V_{ij} represents the systematic component of utility explained by contract attributes and is a function of net returns; $F(\cdot)$ is a function describing farmers' valuation of stochastic returns under the contract, allowing for the possibility

of a nonlinear relationship, and ε_{ij} is the random component of utility accounting for unobserved factors unknown to the researcher.

Based on random utility theory, farmers choose to enter into a conservation contract if the contract provides them with the highest utility, i.e. $U_i = \max(U_{ij}, U_{iq})$ where U_{iq} is the utility obtained if the farmer chooses to remain with the *status quo* or what they are currently doing on their operation. Following Hensher et al. (2005), the probability of entering into the conservation contract can be written as $\mathbf{P}(V_{ij} + \varepsilon_{ij} \geq V_{iq} + \varepsilon_{iq}) = \mathbf{P}(-\Delta\varepsilon_i \leq \Delta V_i)$. While V_{ij} and V_{iq} are not separably identifiable, the difference between the two utilities (ΔV_i) is. The difference in utilities can be expressed as $\Delta V_i = f[F(\Delta\pi_i(\sigma_\pi^2)), X_i; \boldsymbol{\beta}]$, where $\boldsymbol{\beta}$ is the vector of parameters of the utility function (e.g. marginal utilities).

3.5.2 Choice under uncertainty and risk preferences

A concept commonly associated with risk is variance, the dispersion of potential outcomes around its mean (Hardaker et al., 2004). An event is thought to be riskier, the higher the dispersion around its mean (i.e. the higher the variance). Hence, the expected value or mean $E[x]$ and the variance of an attribute (σ_π^2) can be used as factors to analyze individuals' responses to risk. This method is known as the mean-variance approach. The mean variance approach has been used in stated choice applications to study variability in attributes (Li et al., 2010). The mean-variance approach can be represented by a corresponding variant, the mean-standard deviation approach (Hardaker et al., 2004). While the mean-variance (mean-standard deviation) approach to modeling risk in decision making can be attractive, it is more restrictive in that it does not allow for the estimation of a quantitative measure of risk attitude.

3.5.2.1 Expected utility

Decisions under risk and risk preferences have long been evaluated using both expected utility theory and prospect theory. Expected utility theory initially introduced by Bernoulli and later refined by von-Neumann and Morgenstern (1945) postulates that individuals act as if they maximize expected utility. Under expected utility theory, individuals make decisions between gambles by evaluating the function $EU = \sum p_m U_m$; where E is an expectation operator, and U_m is the utility associated with a monetary outcome x_m with probability of occurrence p_m .

Assuming constant relative risk aversion (CRRA), the utility expression can be specified using a general power specification (Pratt, 1964). Individual utility for monetary outcomes can be specified as follows:

$$(3.1) \quad U(\pi) = \begin{cases} \frac{x^{1-\alpha}}{1-\alpha} & \text{if } \alpha \neq 1 \\ \ln x & \text{if } \alpha = 1 \end{cases}$$

where α represents the risk aversion coefficient (Pratt, 1964). If $\alpha=0$, the utility function converges to a linear utility function (expected value) indicating risk neutrality. If $\alpha>0$, the utility function over net returns is concave indicating risk aversion. On the other hand, values of $\alpha<0$ indicate risk seeking attitudes. CRRA utility specifications are widely used in the literature as they are simple to implement making them tractable in empirical applications (Meyer, 2010). For a review of other functional forms see Meyer (2010).

3.5.2.2 Prospect theory

While expected utility has been widely used in modeling decisions under risk, it has received some criticism due to its failure to represent individuals' behavior in some empirical applications (e.g. Allais paradox -Allais, 1953). In a seminal paper, Kahneman and Tversky (1979) proposed prospect theory as an alternative to expected utility theory to model decisions under risk. In prospect theory, probabilities are replaced by decision weights that represent the impact of the outcome from the appeal of the prospects evaluated (Kahneman and Tversky, 1979).

In prospect theory, individuals evaluate the function $\sum w(p_m)\nu(x_m)$ when faced with a gamble (prospect); where ν_m is a value function (utility) and $w(p)$ is a probability weighting function with $w(0)=0$ and $w(1)=1$ (Kahneman and Tversky, 1979). Decision weights are used because as empirical research has shown, decision makers do not treat probabilities linearly, rather they transform probabilities by assigning different weights to low and high probabilities (Gonzalez and Wu, 1999). Under this assumption, risk attitudes are determined by both, the utility from monetary outcomes (ν) and the probability weighting function $w(p)$. Here, the value function ν can take different specifications. In this study, the utility specified in equation (3.1) will be adopted. Different probability weights have been proposed in the literature of which the most commonly used functions are (Stott, 2006):

- i. TK-PWF: The Tversky and Kahneman (1992) probability weighting function is a one-parameter function. When $\gamma=1$ the weighting function is reduced to the linear form: $w(p)=p$. The function is specified as follows:

$$(3.2) \quad w(p_m) = \frac{p_m^\gamma}{\left(\sum_m p_m^\gamma\right)^{\frac{1}{\gamma}}}, \quad \gamma > 0$$

- ii. GE-PWF: The Goldstein and Einhorn (1987) probability weighting function is a two-parameter function. This function is reduced to the TK-PWF when $\tau = 1$. This function takes the following specification:

$$(3.3) \quad w(p_m) = \frac{p_m^\gamma}{p_m^\gamma + \sum_{k \neq m} p_k^\gamma}, \quad \gamma, \tau > 0$$

- iii. P1-PWF: This function is a one-parameter probability weighting function proposed by Prelec (1998), and is specified as follows:

$$(3.4) \quad w(p_m) = e^{-(\ln p_m)^\gamma}, \quad \gamma > 0$$

- iv. P2-PWF: This function is a two-parameter probability weighting function proposed by Prelec (1998). P1-PWF is a special case of the P2-PWF when $\tau = 1$. The function is specified as:

$$(3.5) \quad w(p_m) = e^{-\tau(-\ln p_m)^\gamma}, \quad \gamma, \tau > 0$$

In these probability weighting functions, γ is the parameter that controls the curvature (shape) of the functions, allowing for both concave and convex regions of the function. If $\gamma < 1$, the function is characterized by an inversed S-shape with overweighting ($w(p) > p$) of low probabilities and underweighting ($w(p) < p$) of high probabilities. Conversely, if $\gamma > 1$, the function is characterized by a S-shape with underweighting of low probabilities and overweighting of high probabilities. For the two-parameter weighting function (i.e. GE-PWF and P-PWF), the additional parameter τ controls the elevation of the inflection point where the function goes from concave to convex (or convex to concave). If individuals weigh probabilities

equally (assign the same weight to low and high probabilities), then a linear probability weighting function results, where $w(p_m) = p_m$.

Separable decisions weights can be used. That is, probability weights can depend on the original probability only and not be affected by the outcome of interest. In a later study, Tversky and Kahneman (1992) proposed cumulative prospect theory, allowing the probability weighting functions to also depend on the outcomes.

3.5.2.3 Incorporating risk in the random utility framework

One of the approaches to evaluate the effect of risk is the mean-variance approach. Under this approach, the variance of an attribute is assumed to be a direct source of disutility. Introducing the mean-variance approach into the random utility framework, the systematic component of the indirect utility function can be written as:

$$(3.6) \quad V = \beta_0 + \beta_x E[x] + \beta_\sigma \sigma_x^2 + \sum_k \beta_k X_k$$

where $E[x]$ is the expected value (mean) of the stochastic attribute, estimated as $E[x] = \sum_m p_m x_m$; σ_x^2 is the variance of the stochastic attribute, estimated as $\sigma_x^2 = E[x^2] - E[x]^2$; and β_σ is the parameter associated with the variance, directly capturing an individual's response to the variability in the stochastic attribute x . X_k contains the deterministic attributes (attributes for which the outcome is known with certainty); and β_k is a vector of parameters associated with the deterministic attributes.

A richer specification following Hensher et al. (2011) combines the elements of expected utility and prospect theory into the random utility model. Using expected utility theory to model

risk allows for the estimation of individuals' risk preferences based on the curvature of their utility over the stochastic attribute. This approach also draws from prospect theory the introduction of probability weights (Equation 1.2-1.5) to allow for individuals to subjectively assign decision weights to the original probabilities. This approach results in a non-linear utility specification within the random utility model. In addition, this approach is more flexible in that it allows for the estimation of a utility parameter for net returns in addition to farmers' risk attitudes. By embedding the extended utility term into the random utility model, the systematic component of indirect utility can be written as follows:

$$(3.7) \quad V = \beta_0 + \beta_r \left[\sum_m w(p_m) \frac{x_m^{1-\alpha}}{1-\alpha} \right] + \sum_k \beta_k X_k$$

where β_r is the parameter associated with the risky attribute x ; $w(p_m)$ is a non-linear probability weighting function; α is an attribute-specific risk aversion coefficient, representing individuals' attitude towards the risk associated with the stochastic attribute; X_k is a set of deterministic attributes (attributes for which the outcome is known with certainty); and β_k is a vector of parameters associated with the deterministic attributes. Hensher et al. (2011) refer to the term $\beta_r \left[\sum_m w(p_m) \frac{x_m^{1-\alpha}}{1-\alpha} \right]$ as the attribute specific expected utility.

3.5.3 Model estimation

Two modeling approaches are used to model the risk associated with net returns under a conservation contract. The first model considers the stochastic nature of net returns within the random utility framework by using a mean-standard deviation approach (using the standard deviation instead of the variance), however the assumption of risk neutrality is implicitly

imposed. The second model is an attribute specific extended expected utility model, which is a more complete specification as it takes into consideration the stochastic nature of farmers' net returns and risk preferences by embedding expected utility and prospect theory within the random utility framework, allowing for the estimation of a parameter for net returns in addition to farmers' risk attitudes.

3.5.3.1 Mean-standard deviation approach

In each choice situation, farmers faced potential changes in net returns when adopting a conservation contract under each choice scenario. Farmers were presented with three potential net return outcomes: gains in net returns ($\Delta\pi^+$), no changes in net returns (π_0), and losses in net returns ($\Delta\pi^-$). The baseline net return (π_0) indicates that farmers will receive 100% of their annual level of net returns. The gain (loss) in net returns is the percentage above (below) their current level of net returns (100%). Expected net returns can then be estimated as the probability weighted average of the three potential outcomes Equation (3.8).

$$(3.8) \quad ENR = p_1(\pi_0 - \Delta\pi^-) + p_2(\pi_0) + p_3(\pi_0 + \Delta\pi^+)$$

In this study, a variant of the mean-variance approach was estimated using the standard deviation of expected net returns. This model is estimated to study the effect that expected net returns and the variation of net returns under a conservation contract exerts on farmers willingness to enroll in the conservation contract. The indirect utility model estimated using the mean-variance approach to model risk in net returns within the choice model is then given by the following expression:

$$\begin{aligned}
(3.9) \quad V_i = & \beta_0 + \beta_{NR}ENR + \beta_{SD}SD_NR + \beta_{pay}Payment + \beta_{prg}Program + \beta_{nt}NT_j + \beta_{nt_sq}NT_j \times NT_{SQ} \\
& + \beta_{rot}Rot_j + \beta_{rot_sq}Rot_j \times Rot_{SQ} + \beta_{ccrop}Cover_j + \beta_{ccrop_sq}Cover_j \times Cover_{SQ} + \beta_{VRA}VRA_j \\
& + \beta_{VRA_sq}VRA \times VRA_{SQ} + \beta_{LE}LowEnv + \beta_{ME}MidEnv
\end{aligned}$$

where ENR is expected net returns and SD_NR is the standard deviation of net returns. Pay represents the level of incentive payment in dollars per acre; $Program$ is a binary variable taking a value of 1 if the program through which the incentive is offered is a carbon payment through a carbon market and 0 if the program is a direct government payment. NT , Rot , $Cover$, and VRA are binary variables indicating if continuous no-till, conservation crop rotation, cover crops, and VRA of inputs were included in the practices required under the conservation contract. NT_{SQ} , Rot_{SQ} , $Cover_{SQ}$, and VRA_{SQ} are binary variables indicating if a farmer has already adopted the specified conservation practices in the proposed conservation bundle. These parameters were interacted with the practices in the contract to adjust for the effect of prior practice adoption on the willingness of farmers to enter into the contract and to identify the maintenance payment necessary for farmers to maintain these practices. $LowEnv$ and $MidEnv$ denote the level of perceived offsite environmental benefits from the conservation contract, and could be low ($LowEnv$), medium ($MidEnv$), or high (used as the base case during estimation)⁵.

The parameter β_{SD} directly captures farmer's response to the variability of net returns (risk) under the conservation contract and it is expected to be a direct source of disutility. On the other hand, the parameter associated with expected net returns (β_{ENR}) is expected to be positive under the assumption that farmers are profit maximizers. The parameters β_{nt} , β_{rot} , β_{ccrop} , β_{VRA} are expected to be negative. Since adopting conservation practices may require additional

⁵ The levels of offsite environmental performance are a qualitative description of perceived benefits, and therefore can be subjectively interpreted by the decision maker.

investment, may increase labor requirements, and may require changing crop management; a lower willingness to adopt the contract is expected when this requires that the farmers adopts new practices into their operation. A larger negative effect is expected for practices that are not as widely adopted like cover crops and VRA of inputs. In contrast, the parameters β_{nt_sq} , β_{rot_sq} , β_{ccrop_sq} , and β_{VRA_sq} are expected to be positive, as farmers with previous conservation experience may be more likely to enter into a conservation contract, particularly when the contract requires practices already in place on their farms. Incentive payment is an important element of conservation contracts and is expected to be a positive factor ($\beta_{pay} > 0$) in farmers' decision to enroll in the contract. There is no a prior expectation regarding the sign of β_{prg} as there are different factors that could both negatively or positively affect farmers response. First, while a carbon payment can represent an additional source of income for the adoption of practices, payments are subject to market fluctuations and are not fixed as they would be under a federal conservation program. Second, carbon markets may produce a negative response because of negative views on the climate change debate potentially originating these carbon trading schemes. On the other hand, some farmers may favor a market-based mechanism where those using the carbon offsets (in this case, GHG emitter companies) pay for the sequestration service and not the government (Ribaud et al., 2010). Farmers are expected to have preference for contracts with higher offsite environmental benefits (used as the base case in estimation), thus a low or medium level of benefits is expected to be less preferred by farmers (i.e. β_{LE} and $\beta_{ME} < 0$).

3.5.3.2 Attribute specific extended expected utility

Following Hensher, Greene, and Li (2011), the attribute specific expected utility term that models the stochastic component of net returns for the situation modeled here is given by the following expression:

$$(3.10) \quad EEUT = \beta_{EUT} \left\{ \left[w(p_1)(\pi_0 - \Delta\pi^-)^{1-\alpha} + w(p_2)(\pi_0)^{1-\alpha} + w(p_3)(\pi_0 + \Delta\pi^+)^{1-\alpha} \right] / (1-\alpha) \right\}$$

where expected utility is the probability weighted average utility of the potential three net returns outcomes, and β_{EUT} is a utility parameter measuring farmers preference for net returns. This parameter is expected to be positive under the assumption that farmers are utility maximizers. Risk perception is an important factor in individual's choices (Weber and Milliman, 1997), especially in the agricultural sector where outcomes are stochastic in nature (Beal, 1996). A higher risk associated with the conservation contract is expected to result in a lower willingness to enroll in the contract. Under this model specification, α is the risk attitude towards net returns and is expected to be positive a priori, indicating risk aversion. Since risk attitude can vary across individuals, the risk attitude parameter was modeled as a function of regional characteristics and farm size measured by total acreage such that, $\alpha = \alpha_0 + \alpha_1 Western + \alpha_2 Central + \alpha_3 FarmSize$.

The model where the attribute specific expected utility term is embedded into the random utility framework to model decisions under risk is estimated using the following functional form for the systematic component of the indirect utility function:

$$(3.11) \quad \begin{aligned} V_{ij} = & \beta_0 + EEUT_{ij} + \beta_{pay} Payment_j + \beta_{prg} Program_j + \beta_{nt} NT_j + \beta_{nt_sq} NT_j \times NT_{SQ} \\ & + \beta_{rot} Rot_j + \beta_{rot_sq} Rot_j \times Rot_{SQ} + \beta_{ccrop} Cover_j + \beta_{ccrop_sq} Cover_j \times Cover_{SQ} \\ & + \beta_{VRA} VRA_j + \beta_{VRA_sq} VRA \times VRA_{SQ} + \beta_{LE} LowEnv + \beta_{ME} MidEnv \end{aligned}$$

In this functional form, the expected net returns (ENR) and the standard deviation of net returns (SD_NR) used to estimate the mean-standard deviation approach in equation (3.9) are replaced by the attribute specific expected utility term ($EEUT$) specified in equation (3.10). Four different models were estimated using the probability weighting specifications outlined in Equations (3.2) to (3.5) and an additional model was estimated where the probability weighing function was assumed to be linear ($w(p) = p$). Separable decision weights were used, that is, probability weights depend on the original probabilities only, and not on the outcomes. Since farmers form their own expectations of potential net returns based on their own (or their peers') experiences, the probability weighing function's parameters are expected to be statistically significant and are expected to result in an overweighting of low probabilities and underweighting of large probabilities as findings in previous empirical applications suggest (Kahneman and Tversky, 1979; Lattimore et al., 1992; Prelec, 1998; Tversky and Kahneman, 1992). Since probability weights can also reveal risk, risk attitude is expected to be larger in the linear probability specification where no weighting functions are applied to the original probabilities.

3.5.3.3 Error component model specification

The models were estimated using a general error component framework to capture heterogeneity across farmers. Let the utility of farmer i ($i=1, \dots, 235$) associated with contract j ($j= 1,2$) in each choice scenario t ($t=1, \dots, 12$) be:

$$(3.12) \quad U_{ijt} = V(\beta, \mathbf{x}_{ijt}) + \theta_j E_{ij} + \varepsilon_{ij}$$

where $V(\cdot)$ is the systematic component of the utility and can take a linear specification following Equation (3.9), or a non-linear specification as described in Equation (3.11). The

models examined are embedded into this general specification, the systematic component of utility ($V(\cdot)$) changes in each model. E_{ij} is the error component or alternative specific random individual effects, included to control for unobserved heterogeneity not accounted for in the model specification; and θ_j is the standard deviation of the error component and assumed to be equal to one. The individual random component ε_{ij} is independent and identically distributed (IID) extreme value Type I (Louviere et al., 2000). The structural model that estimates the conditional probability of farmer i choosing contract j is then given by (Bhat, 1998; Greene, 2012):

$$(3.13) \quad \text{Prob}(y_{it} = 1 | E_{ij}) = \frac{\exp[V(\beta, \mathbf{x}_{ijt}) + \theta_j E_{ij}]}{\sum_j \exp[V(\beta, \mathbf{x}_{ijt}) + \theta_j E_{ij}]}$$

A restriction was imposed by setting the systematic component of the utility associated with the *status quo* equal to zero ($V_{i0t} = 0$). Models were estimated using the PROC NLMIXED procedure In SAS⁶.

3.5.3.3.1 Risk premium

The risk premium P , is the dollar amount that would need to be paid to make risk averse farmers indifferent between adopting a risky contract versus a risk-free contract. Farmers are said to be indifferent between the two contracts if the probability of adoption between the two contracts is equal as follows:

⁶ The PROC NLMIXED procedure fit the model by maximizing an integrated likelihood approximation by adaptive Gauss-Hermite quadrature.

$$(3.14) \quad \Lambda\left(\beta_0 + \tilde{\beta}_r E[U(\pi)] + \sum_k \tilde{\beta}_k X_k\right) = \Lambda\left(\beta_0 + \tilde{\beta}_r U(E[\pi] - P) + \sum_k \tilde{\beta}_k X_k\right)$$

where $\Lambda(\cdot)$ is the logistic cumulative distribution function, and P is the risk premium. Equation (3.14) shows the probability of a risk-free contract in the right hand side, and the probability of adopting a risky contract in the left-hand side. This expression can be further simplified to:

$$(3.15) \quad E[U(\pi)] = U(E[\pi] - P), \quad \text{or}$$

$$(3.16) \quad (E[U(\pi)])^{-1} = E[\pi] - P$$

The right hand side of Equation (3.16) is also known as the certainty equivalent (CE) and represents the sure amount farmers will be willing to accept to avoid a risky contract with a higher return. The risk premium then is estimated as the difference between the expected net returns (mean of net returns) under the contract and the certainty equivalent (Pratt, 1964).

$$(3.17) \quad P = E[\pi] - CE$$

The risk premium represents the amount farmers would be willing to pay to avoid a risky contract by replacing it for a contract with a sure payoff, that is, a contract where they obtain the mean net returns (expected profits under the contract). The risk premium was estimated numerically for each farmer using the parameter estimates from Equation (3.11) and individual farmer data. The average across farmers is reported in Table 3.8.

3.5.3.3.2 *Model assessment*

Since the different models evaluated in this section have different parameters and specifications for the probability weighing function, a test for non-nested hypothesis is necessary to judge goodness of fit across the different models. A method commonly used to evaluate a model in empirical applications is the likelihood ratio index or Pseudo R-squared (Greene, 2012). Let each model be indexed by g ($g = 1, \dots, G$) with a set of K_g parameters given by $\hat{\beta}$, the likelihood ratio index adjusted for the number of parameters is then given by (Ben-Akiva and Lerman, 1985):

$$(3.18) \quad (\bar{\rho}_g^2) = 1 - \frac{L_g(\hat{\beta}) - K_g}{L(0)}$$

where $L_g(\hat{\beta})$ is the log-likelihood for the estimated model, $L(0)$ is the log-likelihood for the constant only, and K_g is the number of parameters in the model. The measure of $-2L_g(\hat{\beta}) - 2K_g$ is known as the Akaike Information Criterion (AIC) and is also used to compare models, where a smaller AIC value is better (Greene, 2012). In order to discriminate between two models (model 1 and model 2), on the basis of which performs better, Ben-Akiva and Swait (1986) proposed a test where under the assumption that model 1 is the true specification, and given that the probability that the measure of fitness for model 2 ($\bar{\rho}_2^2$) is greater than that of model 1 ($\bar{\rho}_1^2$) by some $Z > 0$, it asymptotically holds that:

$$(3.19) \quad \text{Prob}\left(\left|\bar{\rho}_2^2 - \bar{\rho}_1^2\right| \geq Z\right) \leq \Phi\left(-\sqrt{-2ZL(0) + (K_2 - K_1)}\right)$$

where Φ is the standard normal cumulative distribution function. Equation (3.19) represents the upper bound for the probability of incorrectly selecting the wrong model based on the goodness of fit (Ben-Akiva and Lerman, 1985).

3.6 Survey Design and Data

3.6.1 Survey methods

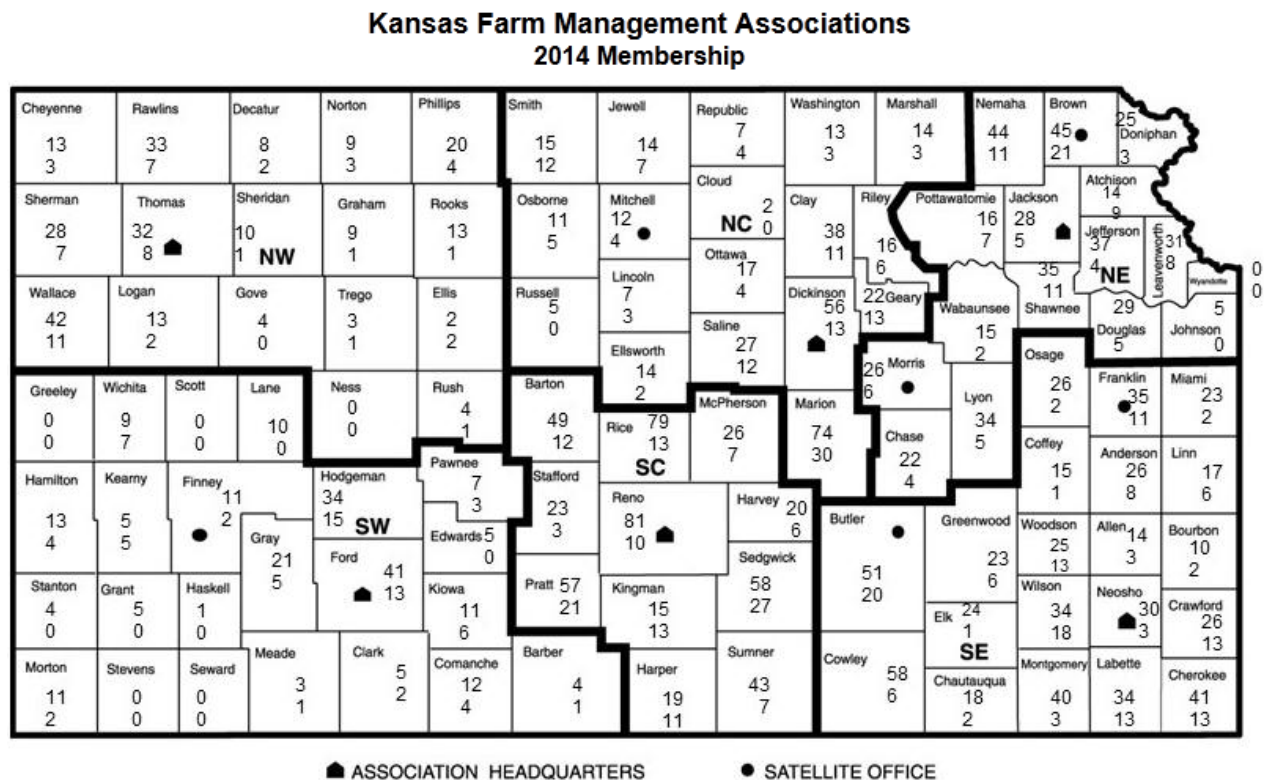
This study examined the adoption of conservation practices by farmers in Kansas. A stated choice survey was administered during a series of workshops held across 10 locations spanning the state of Kansas from December 2013 to March 2014. Workshop locations were selected based on different weather, landscape and farm demographic characteristics. The cities where the workshops were held are: Salina, Great Bend, Colby, Dodge City, Wellington, Pratt, Hiawatha, Topeka, Manhattan, and Parsons, Kansas. Prior to administering the stated choice experiment during the workshops, the stated choice survey was field tested with farmers during three focus groups held in Manhattan, Salina and Wellington.

A sample of farms was obtained from the Kansas Farm Management Association (KFMA), which has approximately 2,300 farms across Kansas in their database that produce crops and livestock. Of these farms, approximately 76% are identified as primarily crop producers and 16% are identified as crop/livestock producers. A map depicting KFMA's membership by county is shown in Figure 3.2. Working with members of KFMA allowed for respondent data to be matched to historical financial data collected by KFMA for the participating farms. A total of 1,513 farmers from the KFMA were mailed letters asking them to attend a workshop. Of the farmers contacted, 40 were no longer farming, were deceased or could not be located; and 432 responded to the letter. The letters of request resulted in about 250

of the farmers attending the workshops. The rest of the farmers who responded were interested in participating, but could not attend the workshops on the dates these were held. This resulted in an adjusted response rate of approximately 30%, and an attendance rate of 17%. Workshop attendees were compensated for their time and travel expenses with a stipend of \$125.

The workshops consisted of an introductory presentation covering the basic aspects of the conservation practices under study, a time for farmers to answer a survey questionnaire and the stated choice experiment, and a focus group to discuss farmers' views on conservation. Prior to administering the stated choice experiment, farmers were asked to complete a survey with questions to elicit their farming history, farm operation, and conservation practices used on their farm. Subsequently, farmers were provided with general guidelines on how to respond to the stated choice experiment questions. After farmers completed the stated choice exercise, a focus group was conducted where farmers discussed their views on conservation, their experience using conservation practices, benefits and disadvantages from using conservation practices on their farm, and their experience participating in conservation programs.

Figure 3.2 Kansas Farm Management Association membership by county



Top number in each county = Number of Farm Units per County

Bottom number in each county = Number of Extra Partners or Persons in the Multi-Operator farm Units

Source: KFMA (2015) <http://www.agmanager.info/kfma/>

3.6.2 Survey data

Data from farmers with incomplete responses for needed variates were not considered, leaving 234 farmers' data for analyses. Table 3.1 presents these farmers demographics reported in the survey and compares them to the 2012 U.S. Census of Agriculture (NASS-USDA, 2014) and the demographics of KFMA members in 2013 (KFMA, 2014). All of the farmers in the study were between 20 and 84 years of age, with a sample average of 56 years which could be considered representative of the average Kansas farmer (58 years – as reported in the U.S. Census of Agriculture). However, the average size (including CRP land) of farm operations in the sample (2,508 acres and sales value of \$400,000 to \$599,999) is larger than the average farm size of 747 acres and sales value of \$298,845 in Kansas, as reported in the 2012 Census of Agriculture. It should be noted that, small size farms, hobby/residential farms or farms operated by retired operators (sales < \$250,000) represent a significant share of the total U.S. farm population (Lambert et al., 2007). In the U.S. Census of Agriculture, farmers with sales lower than \$99,999 represent roughly 74% of the total farms (NASS-USDA, 2014). This study focuses on medium to large farms, excluding small hobby farmers, retired farmers, and very large operations. Medium and large farmers were chosen as the study group as the goal was to examine farmers that produce a higher percentage of the overall crop production. In addition, this group was selected because farm size plays an important role for conservation practice adoption, particularly for practices that are management intensive as they require operators to be devoted to farming because of the additional learning, time and financial investment needed (Lambert et al., 2007).

When comparing the farm demographics of the farmers who participated in the survey to those of all KFMA members, the sample is representative of the KFMA group. KFMA members are a good sample of farmers to study as they generally operate medium to large size farming operations, which is the main target of this study. Hence, results in this study should be

interpreted as representing conservation practices adoption decisions by medium to large farm operators in Kansas.

Figure 3.3 shows the percentage of farms whose operators reported using the selected conservation practices. While the adoption numbers are high, some farmers may no longer use the practice or use the practice on a small amount of their crop land. A higher percentage of farmers reported the use of continuous no-till (62.4%) and conservation crop rotation (62.8%). While 86% of the farmers had periodically used no-till practices on a particular crop (rotational tillage), only 62.4% of them had practiced continuous no-till on some part of their farm operation. Consistent with findings by (Grandy et al., 2006), only a fraction of no-till producers have adopted continuous no-till. A fewer number of farmers indicated that they had used cover crops (33.3%) and VRA of inputs (27.8%). The adoption rates of these practices was high in the study group compared to adoption rates previously reported (CTIC, 2013; Schimmelpfennig and Ebel, 2011; Singer et al., 2007), this is due to the nature of the survey which focuses on intensification of conservation. Thus, the survey group sample targeted and design made more favorable for farmers that had already adopted some sort of conservation on their farm.

Table 3.1 Average farm characteristics

Variable	N	Mean	SD	Min.	Max.	Mean 2012 Census of Agriculture	Mean 2013 KFMA
Age (yrs.)	234	56	13	20	84	58	----
Acres	234	2,508	1,981	110	14,875	747	2,196
Sales	234	6.20 ^b	2.04	1	9	\$ 298,845	\$618,416

^a Source: National Agricultural Statistics Service, USDA (2014)

^b Mean sales of 6.20 corresponds to the sales category of \$400,000 to \$599,999

Figure 3.3 Percentage of farmers who currently used the selected conservation practices.

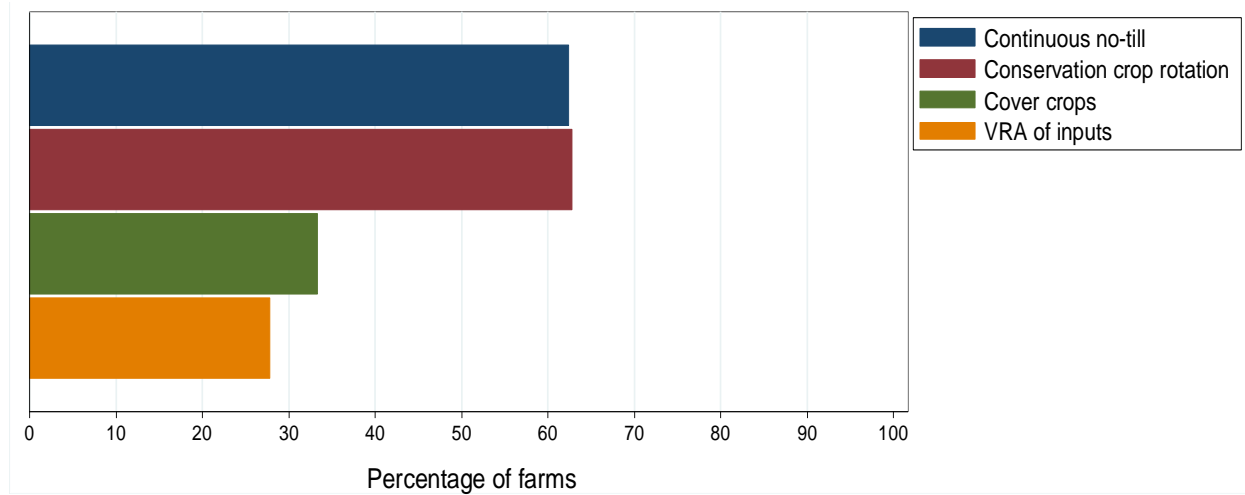
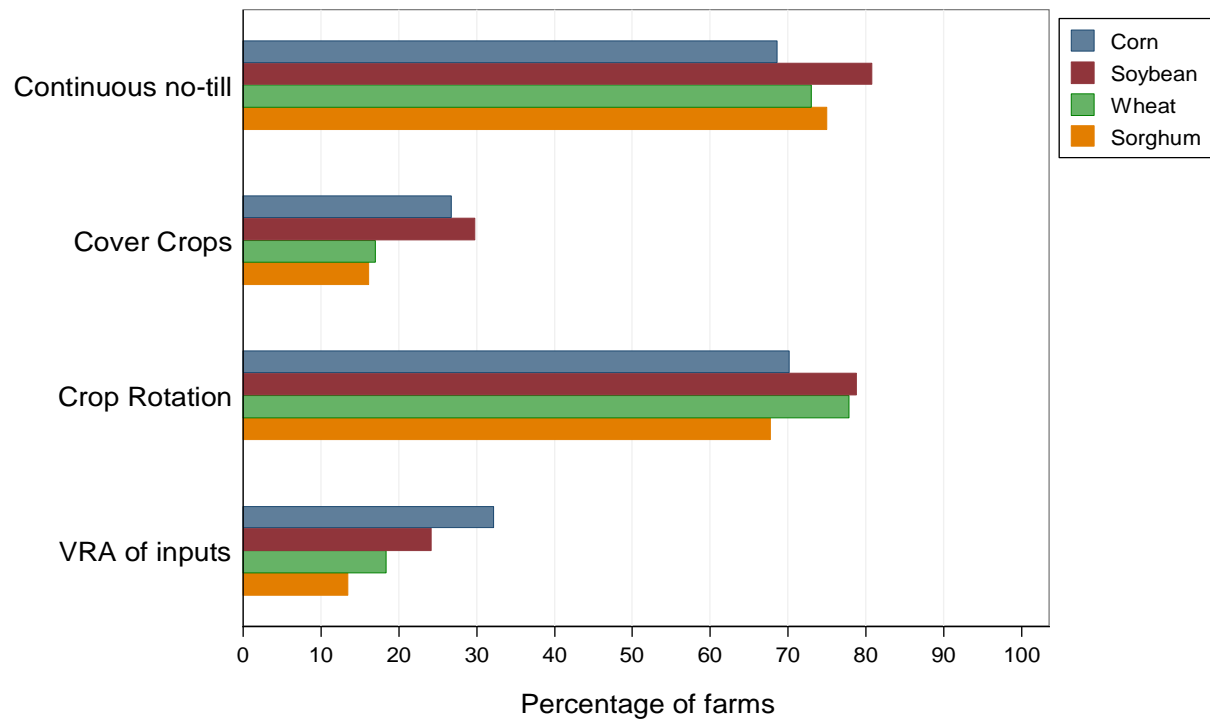


Figure 3.4 Percentage of farmers who currently use or have used the selected conservation practices for select cash crop.



Results of adoption rates at the crop level (Figure 3.3) indicate the highest rate of adoption of no-till is in soybeans (79.9%), while the lowest rate of adoption is in corn (68.0%). In the case of VRA of inputs, corn has the highest rate (32.4%) and sorghum has the lowest rate (13.8%). Several of the farmers who indicated using these practices have not fully adopted them on all their cropland; some of them have only experimented, whereby the minimum percentage of cropping land under each selected practice ranges from 1 to 3 percent (see Figure 3.5). Only a small fraction of farmers who have adopted conservation practices have participated in conservation programs. The program with the highest participation rate is Conservation Reserve Program (CRP), with 61.8% of the farmers participating. With respect to programs that provide incentive payments for the adoption of management practices, farmers reported current or past participation in EQIP (38.1%) and CSP (22.8%). This result is consistent with findings by (Reimer and Prokopy, 2014) who found higher rates of participation in CRP, and low participation rates in the EQIP and CSP programs.

The percentage of farmers who receive incentive payments through EQIP or CSP for using the practices in this study is reported in Table 3.2. Among farmers who have adopted these practices, continuous no-till and cover crops seem to be the most common practices for which they receive incentive payments through CSP (18.3% for no-till and 19.1% for cover crops). However, it is important to note that payments for tillage practices could include other types of conservation tillage and not strictly continuous no-till. A smaller percentage of cover crop adopters receive payments through EQIP (1.6%). VRA of inputs, which is the least adopted practice, has the lowest rate of incentives being received for its use on-farm.

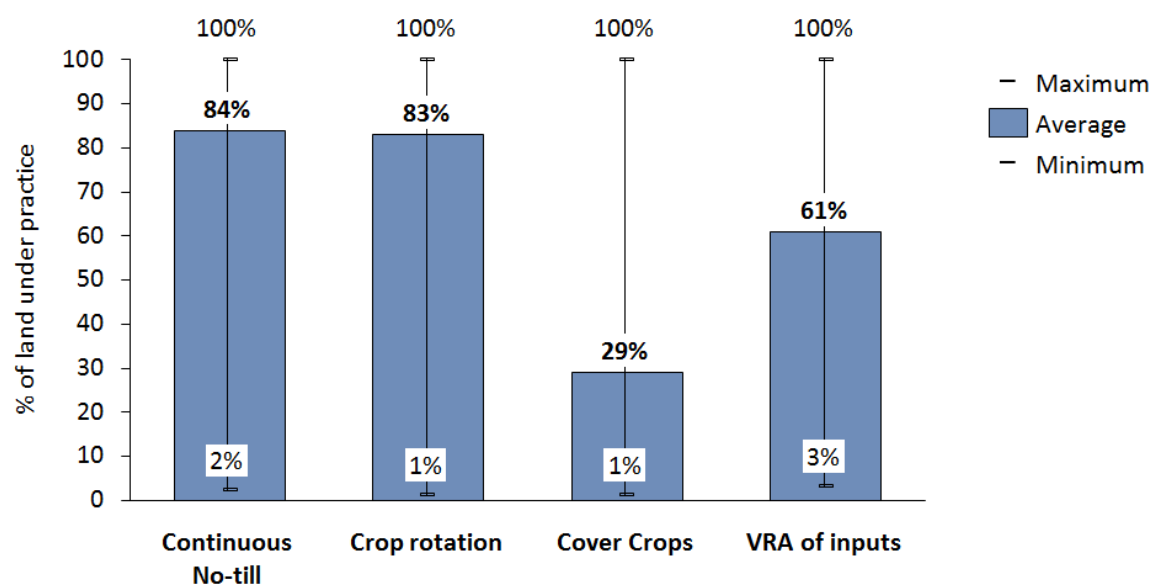
Table 3.2 Farmer receiving incentive payments for practices used

	EQIP (%) ^a	CSP (%)
Continuous no-till	6.62	18.38
Conservation crop rotation	4.48	11.19
Cover Crops	1.37	19.18
Variable rate application of inputs	1.69	8.47

^a Percentage calculated based on the number of current adopters

EQIP = Environmental Quality Incentives Program, CSP = Conservation Stewardship Program

Figure 3.5 Percentage of crop land under each practice



3.6.3 Stated choice design

In order to assess farmers' willingness to adopt and intensify conservation on their farms, farmers were asked to complete a stated choice exercise. The attributes in the contract were selected in a way to mimic current conservation programs. Under current government conservation program, farmers receive an incentive payment for a conservation plan consisting of various conservation practices. In order to address environmental concerns, through monetary incentives, programs like the CSP encourage farmers to maintain existing conservation practices and to intensify conservation on their working lands by adopting new conservation practices (NRCS, 2015a). Farmers who adopt new practices are faced with potential changes in their bottom line as yields and input costs change due to the implementation of new agricultural practices.

Respondents were presented with twelve hypothetical contract choice scenarios with two contract alternatives, a conservation contract and a status quo contract. Contract attributes and attribute levels evaluated are presented in Table 3.3 and are as follows::

- i. *Conservation practices to adopt under the contract:* the conservation practices evaluated were continuous no-till, conservation crop rotations, cover crops and VRA of inputs. The conservation practices were treated as dichotomous attributes in the experimental design to determine if the practice was required under the contract. The practices present in each set were presented in the contract as a bundle to represent different levels of conservation intensification. This attribute was included not only to account for adoption but also for conservation intensification. Some practices are currently widely adopted; however, conservation programs strive for additionality by encouraging farmers to undertake more conservation efforts while also providing incentives to maintain and manage existing conservation practices.

- ii. *Incentive payment*: the annual per acre incentive payments evaluated were \$0, \$15, \$30, \$45, \$60, and \$75. These payments, while hypothetical, are similar to base payments reported under CPS and EQIP in Kansas⁷.
- iii. *Incentive program*: this study evaluated two incentive programs, a federal program (EQIP/CSP-like program) and a carbon credit payment through a carbon market. Payments for carbon sequestration can be established through contracts where farmers get paid per ton of carbon sequestered, as an alternative to per-acre payments for the practices implemented (Antle et al., 2003). To avoid further complicating the choice task in the experiment, in this study farmers were presented with a payment per acre for the practices adopted.
- iv. *Off-farm environmental benefits from adopting conservation practices*: While economic drivers are a main factor in conservation contracts, the decision to adopt conservation practices is also affected by factors other than economic motivations (Bergtold et al., 2012; Chouinard et al., 2008). It has been argued that farmers who are more conservation-minded are more likely to adopt conservation practices (Greiner et al., 2009a), and that a higher level of benefits from conservation motivates greater adoption (Reimer and Prokopy, 2014). This study examined the extent to which the effectiveness of conservation practices in achieving environmental benefits off-farm affects farmers' actions on-farm. Three hypothetical levels of off-farm environmental benefits were included: Low, Medium and High.

⁷ EQIP payment rates for the conservation practices examined in 2012 are: No-till practices=\$12.26/acre; Conservation crop rotation=\$6.73/acre; VRA of fertilizer=\$13.94; and Cover crops=\$27.40 for single species and \$47.15/acre for multiple species. Kansas Practice Payment Schedule for EQIP - Fiscal Year 2012 available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_031993.pdf.

- v. *Riskiness of the contract:* While some agricultural practices have proved to be profitable, they have not been fully adopted. This indicates that there are factors other than the profitability of a technology affecting farmers' choices. An important factor farmers consider is the risk associated with a technology. Risk is introduced to the operation as new practices are adopted that could increase the variability of costs, crop yields, and returns. In addition, the restrictions of the contract may introduce inflexibility which may affect a farmer's ability to react to external events. For example, if a farmer enrolls in a contract that requires him to plant cover crops for the next five years, planting a cover crop in a dry year may affect the yields of the following cash crop.

In this study, the riskiness of the contract was introduced in the experiment by presenting a distribution of potential changes in average net farm income over the timeframe of the contract with corresponding probabilities of occurrence. The design of the experiment had four distributions for potential changes in net returns for adopting the contract. The distributions of potential changes in net returns were assumed symmetric with equal potential gains and losses, varying only by the level of potential changes: (1) 5% Loss, 0% change, 5% Gain; (2) 10% Loss, 0% change, 10% Gain; (3) 15% Loss, 0% change, 15% Gain; and (4) 20% Loss, 0% change, 20% Gain. The design also consisted of four distributions of probabilities associated with the potential changes in net returns. Two of the probability distributions are symmetric with equal probability of observing losses and gains. The first distribution (P: 30% of loss, P: 40% of no change, P: 30% of gains) is meant to represent a scenario where the outcomes are more uncertain with the probability of occurrence of the three outcomes being almost equal. The second distribution (P: 10% of loss, P: 80% of no change, P: 10% of gains), represents a

distribution where there is a high probability that net returns will not change, with a low and equal probability of obtaining a loss or a gain. The third distribution (P: 5% of loss, P: 60% of no change, P: 35% of gains) is more heavily weighted towards observing a gain than to observing a loss, while the fourth distribution (P: 35% of loss, P: 60% of no change, P: 5% of gains) is more heavily weighted towards losses than to gains. While farmers were only presented with three probability outcomes (a discrete distribution as opposed to a continuous distribution), for illustration purposes Figure 3.6 depicts that distributions that are intended to be represented in the design, using the example where the distribution of outcomes is 20% Loss, 0% change, 20% Gain.

Figure 3.6 Distribution of the probabilities of net returns change in stated choice design

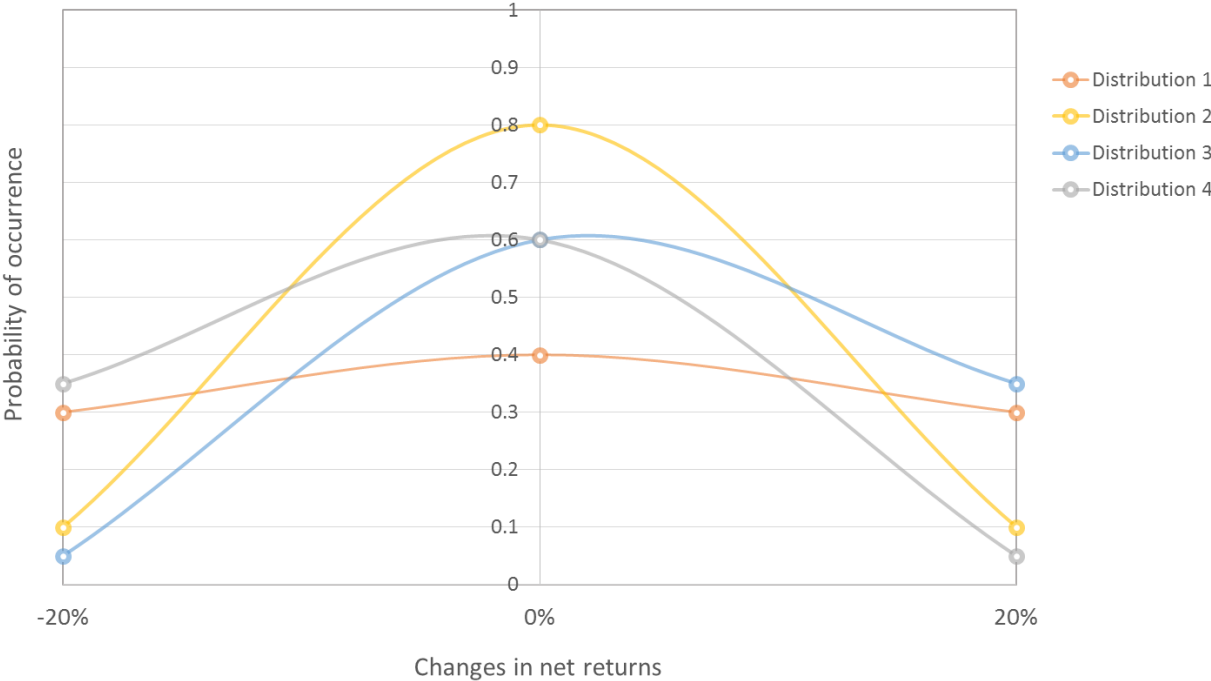


Table 3.3 Contract attributes and attribute's levels

Contract Feature	Description	Levels												
Continuous no-till	Planting crops directly into the crop residue without disturbing the soil in all the crops in rotation in a particular field.	Included, Not included												
Conservation crop rotation	Three or more year rotation with three or more crop types, including a combination of high residue crops, grasses and/or legumes.	Included, Not included												
Cover Crops	Planting a single or multiple cover crop species between regular cash crops for primarily conservation purposes.	Included, Not included												
VRA of inputs	Use of site-specific information for input application rates within a field, including sensor-based and/or map-based methods.	Included, Not included												
Incentive payment	Payment (\$/acre) offered annually during the length of the contract.	\$0/acre, \$15/acre, \$30/acre, \$45/acre, \$60/acre, \$75/acre												
Incentive Program	Type of mechanism through which the payment is offered, administered and regulated.	Federal Program or Carbon Credit Payment through a Carbon Market												
Offsite Environmental Impact	Potential off-farm environmental benefits of the practices stated under each scenario (e.g. downstream water and air quality).	Low, Moderate, High												
<i>Riskiness: Impact on Net Returns</i>														
Average Change in Net returns over 5 years ¹	Distribution of income changes over a 5 years period (length of the contract).	<table><tr><td>-20%</td><td>-15%</td><td>-10%</td><td>-5%</td></tr><tr><td>0%</td><td>0%</td><td>0%</td><td>0%</td></tr><tr><td>+20%</td><td>+15%</td><td>+10%</td><td>+5%</td></tr></table>	-20%	-15%	-10%	-5%	0%	0%	0%	0%	+20%	+15%	+10%	+5%
-20%	-15%	-10%	-5%											
0%	0%	0%	0%											
+20%	+15%	+10%	+5%											
Probability of changes in net returns ²	Probability distributions for potential net income changes.	<table><tr><td>5%</td><td>30%</td><td>35%</td><td>10%</td></tr><tr><td>60%</td><td>40%</td><td>60%</td><td>80%</td></tr><tr><td>35%</td><td>30%</td><td>5%</td><td>10%</td></tr></table>	5%	30%	35%	10%	60%	40%	60%	80%	35%	30%	5%	10%
5%	30%	35%	10%											
60%	40%	60%	80%											
35%	30%	5%	10%											

^{1,2} Each column represents a distribution. The first row in each column represents losses, second column represents no changes in net returns, and the third row represents gains.

The contract presented to farmers was a standard 5-year contract (like CSP contract length) with verification of compliance by a program professional. A clause included in the contract stated that farmers had to make a full repayment of the incentive payments received plus any administrative costs if they were found in violation of the contract (if they fail to provide the practices stipulated in the contract). The specifications of the contract shown to farmers in the choice experiment are presented in Appendix A.

A fractional-factorial experimental design with 288 choice sets was obtained from a $2^5 \times 6 \times 3 \times 4^2$ full factorial design. This design allows for the identification of main effects and two-way interaction effects (Louviere et al., 2000). The set of choice scenarios chosen was the candidate set with the highest D-efficiency score (D-efficiency = 93.6). The 288 combinations were blocked into 24 blocks with 12 choice sets. Each farmer was presented with 12 choice scenarios, each containing a conservation contract and a constant *status quo* option. An example of a choice set is presented in Figure 3.7. The design was generated using PROC OPTEX in SAS® (SAS Institute Inc, 1999).

Descriptive statistics of the data, including contract attributes, demographics, and farm characteristics used in estimating the models are presented in Table 3.4. Observations from 234 farmers were deemed appropriate for estimation, resulting in 2,808 usable observations.

Figure 3.7 Example of choice task.

Conservation Practices	Continuous No-till Conservation Crop Rotation Cover Crops Variable Rate Application of Inputs												
Incentive Program	Carbon Credit Payment through a Carbon Market												
Incentive Payment	\$45/acre												
	<table border="1"> <thead> <tr> <th></th> <th><u>Average Change in Net Returns Over 5 Years</u></th> <th><u>Probability of Occurrence</u></th> </tr> </thead> <tbody> <tr> <td>Riskiness</td> <td>10% Loss</td> <td>5% Very unlikely</td> </tr> <tr> <td></td> <td>No change</td> <td>60% Likely</td> </tr> <tr> <td></td> <td>10% Gain</td> <td>35% Medium likelihood</td> </tr> </tbody> </table>		<u>Average Change in Net Returns Over 5 Years</u>	<u>Probability of Occurrence</u>	Riskiness	10% Loss	5% Very unlikely		No change	60% Likely		10% Gain	35% Medium likelihood
	<u>Average Change in Net Returns Over 5 Years</u>	<u>Probability of Occurrence</u>											
Riskiness	10% Loss	5% Very unlikely											
	No change	60% Likely											
	10% Gain	35% Medium likelihood											
Off-farm Environmental Benefits	Moderate												

Would you adopt this system or stay with the Status Quo?

☐ **Adopt** ☐ **Status Quo**

Table 3.4 Data summary statistics

Variable	Complete Sample (N=2,808)			
	Mean	SD	Min	Max
Dependent variable: (adopt=1, status quo=0)	0.462	0.499	0	1
<u>Contract attributes:</u>				
Incentive payment (\$/acre-year)	37.121	25.613	0	75
Incentive program (1= carbon market, 0= federal program)	0.504	0.500	0	1
<i>Conservation practices</i>				
Continuous no-till	0.516	0.500	0	1
Conservation crop rotation	0.507	0.500	0	1
Cover crops	0.517	0.500	0	1
Variable rate application of inputs	0.523	0.500	0	1
<i>Percentage change in net returns</i>				
Percentage of loss in net returns	12.46%	5.60%	5%	20%
Percentage of gains in net returns	12.46%	5.60%	5%	20%
<i>Probability of changes in net returns</i>				
Probability of loss in net returns	19.99%	12.75%	5%	35%
Probability of no change in net returns	59.95%	14.14%	40%	80%
Probability of gains in net returns	20.06%	12.75%	5%	35%
<i>Offsite environmental benefits</i>				
Low	0.337	0.473	0	1
Moderate	0.325	0.468	0	1
High	0.338	0.473	0	1
<u>Farm/farmers' characteristics:</u>				
Adopted continuous no-till	0.624	0.484	0	1
Adopted conservation crop rotation	0.628	0.483	0	1
Adopted cover crops	0.333	0.471	0	1
Adopted variable rate application of inputs	0.278	0.448	0	1
Western	0.218	0.413	0	1
Central	0.419	0.493	0	1
Total acres (hundred acres)	25.088	19.814	1.1	148.75

3.7 Results

3.7.1 Model results

3.7.1.1 Mean-variance approach

Results for the mean-standard deviation model are reported in Table 3.5. The parameters estimates for the contract attributes are all statistically significant and have the expected sign. Consistent with prior expectations, higher net returns increases farmers' willingness to enter into the contract. The variability in net returns (standard deviation of net returns) was negative, indicating that farmers' utility under a conservation contract is reduced as the variability of net returns increases. This result reveals aversion to risk, farmers' willingness to adopt a conservation contract declines if the contract is risky. While this model reveals farmers' response to risk, it does not provide a measure of the level of farmers risk attitudes, assuming risk neutrality.

The incentive payment parameter was positive indicating that a higher conservation incentive would increase farmers' willingness to participate in the conservation contract. The results also indicate farmers' preference for federal programs in lieu of carbon credit based programs. The conservation practice parameters were negative; indicating that adding a practice to the contract reduces farmers' willingness to enter into the contract. The parameter estimates associated with interaction between the practices required in the contract and the variable indicating if the farmer had already adopted such practice (e.g. $NT_j \times NT_{SQ}$) were positive. This result indicates that farmers who have already adopted the conservation practices are more likely to enter into a conservation contract. In addition, a lower off-site environmental performance is likely to reduce farmers' enrollment in the conservation program.

Table 3.5 Model estimates for the mean-variance model

	Parameter estimates	Standard Error
Constant	-12.5537 ***	(1.8503)
<i>Expected net returns</i>	0.1191 ***	(0.0183)
<i>St. Dev. of net returns</i>	-0.0336 **	(0.0144)
<i>Payment</i>	0.0492 ***	(0.0025)
<i>Program</i>	-0.2531 **	(0.1037)
<i>NT</i>	-1.2993 ***	(0.1681)
$NT_j \times NT_{SQ}$	1.7732 ***	(0.1998)
<i>Rot</i>	-0.7019 ***	(0.1602)
$Rot_j \times Rot_{SQ}$	0.4561 **	(0.1906)
<i>Cover</i>	-0.7578 ***	(0.1264)
$Cover_j \times Cover_{SQ}$	0.5206 ***	(0.1951)
<i>VRA</i>	-0.8566 ***	(0.1225)
$VRA \times VRA_{SQ}$	0.8695 ***	(0.2039)
<i>LowEnv</i>	-0.3865 ***	(0.1274)
<i>MidEnv</i>	-0.2545 **	(0.1264)
σ_{EC}	2.3615 ***	(0.3568)
No. of Observations	2808	
Log Likelihood	1452.9	
AIC	2937.8	
Pseudo R-squared	0.253	
Adjusted R-squared	0.244	

*, **, *** statistically significant at the 1%, 5% and 10% level. Standard errors in parenthesis.

¹ Carbon Credit Payment through a Carbon Market was used as the base scenario.

The mean-standard deviation model was also estimated using a random parameters logit (results are reported in Appendix B). In this model, significant heterogeneity in farmers' responses to net returns, variance of net returns, conservation program and conservation practices required in the contract were found as evidenced by the significance of their standard deviation estimates. No evidence was found of heterogeneity in farmers' preference for the off-farm environmental impacts of the conservation practices in the contract (see Appendix B).

3.7.1.2 Attribute specific extended expected utility

3.7.1.2.1 Model fit

Results of the models estimated using expected utility and probability weights are reported in Table 3.6. The parameter estimates for incentive payment, incentive program, conservation practices and off-farm environmental benefits are consistent in sign and magnitudes across probability weighting specifications. Parameters results will be discussed in the following section. In terms of goodness of fit, the TK-PWF and GE-PWF models would seem to be preferred based on the adjusted Pseudo R-squared and the Information Criterion (AIC). Results from the Ben-Akiva and Swait (1986) test (Table 3.7) suggest that the GE-PWF is the preferred model, followed by TK-PWF and P2-PWF which are preferred to P1-PWF and to the linear probability weighting specification. For an example of how to interpret results, from the Ben-Akiva and Swait (1986) test consider the results comparing model P1-PWF and TK-PWF in Table 3.7. The resulting probability of 0.006 indicates that the probability that the goodness of fit of P1-PWF is larger than that of TK-PWF in a sample of 2,808 observations is less than 0.006.

Table 3.6 Model estimate results for the attribute specific extended expected utility models

	Linear probability	TK-PWF	GE-PWF (Best model)	P1-PWF	P2-PWF
Constant	-51.7204 *** (8.0624)	-42.7103 (54.2032)	-60.8061 *** (10.1715)	-35.7249 (31.5567)	-43.4662 (64.2332)
Risk attitude parameters (α)					
α_0	0.7528 *** (0.0105)	0.7085 * (0.3718)	0.8135 *** (0.0159)	0.6440 ** (0.3194)	0.7113 * (0.4298)
<i>Western</i>	0.0485 (0.0322)	0.0153 (0.0439)	-0.0610 (0.0414)	0.0117 (0.0084)	0.0156 (0.0553)
<i>Central</i>	0.0125 (0.0087)	0.0082 (0.0195)	-0.0079 (0.0064)	0.0065 (0.0052)	0.0083 (0.0240)
<i>Acres</i>	-0.0004 ** (0.0002)	-0.0002 (0.0005)	0.0002 * (0.0001)	-0.0002 (0.0001)	-0.0002 (0.0006)
Probability weighting parameters					
γ	---	1.1398 *** (0.0994)	0.9607 (0.6510)	0.9916 *** (0.0242)	0.9924 *** (0.0215)
τ	---	---	0.9804 *** (0.0205)	---	1.0185 *** (0.0296)
Contract parameters					
β_r	4.0307 *** (0.6469)	3.2394 (5.5350)	4.7886 *** (0.8371)	2.4154 (3.5555)	3.3127 (6.5216)
<i>Payment</i>	0.0491 *** (0.0025)	0.0494 *** (0.0025)	0.0492 *** (0.0025)	0.0492 *** (0.0025)	0.0494 *** (0.0025)
<i>Program</i>	-0.2501 ** (0.1025)	-0.2462 ** (0.1027)	-0.2474 ** (0.1026)	-0.2502 ** (0.1026)	-0.2462 ** (0.1027)
<i>NT</i>	-1.3622 *** (0.1695)	-1.3650 *** (0.1700)	-1.3506 *** (0.1696)	-1.3645 *** (0.1696)	-1.3643 *** (0.1700)
$NT_j \times NT_{SQ}$	1.8234 *** (0.2031)	1.8308 *** (0.2038)	1.8188 *** (0.2034)	1.8285 *** (0.2033)	1.8304 *** (0.2038)
<i>Rot</i>	-0.6514 *** (0.1608)	-0.6554 *** (0.1616)	-0.6491 *** (0.1611)	-0.6610 *** (0.1609)	-0.6561 *** (0.1619)
$Rot_j \times Rot_{SQ}$	0.4026 ** (0.1938)	0.4143 ** (0.1948)	0.4013 ** (0.1942)	0.4133 ** (0.1940)	0.4147 ** (0.1951)
<i>Cover</i>	-0.7479 *** (0.1265)	-0.7626 *** (0.1271)	-0.749 *** (0.1268)	-0.7530 *** (0.1266)	-0.7639 *** (0.1272)
$Cover_j \times Cover_{SQ}$	0.4950 ** (0.1989)	0.5140 ** (0.2001)	0.4926 ** (0.1994)	0.5081 ** (0.1991)	0.5166 ** (0.2006)
<i>VRA</i>	-0.7953 *** (0.1206)	-0.8038 *** (0.1211)	-0.8053 *** (0.1208)	-0.7962 *** (0.1207)	-0.8041 *** (0.1211)

Table 3.6 continued.

	Linear probability	TK-PWF	GE-PWF (Best model)	P1-PWF	P2-PWF
$VRA \times VRA_{SQ}$	0.7676 *** (0.2061)	0.7735 *** (0.2068)	0.7798 *** (0.2063)	0.7652 *** (0.2063)	0.7737 *** (0.2068)
$LowEnv$	-0.3646 *** (0.1255)	-0.3675 *** (0.1258)	-0.3755 *** (0.1257)	-0.3653 *** (0.1255)	-0.3671 *** (0.1258)
$MidEnv$	-0.2401 * (0.1253)	-0.2497 ** (0.1257)	-0.2578 ** (0.1256)	-0.2410 * (0.1253)	-0.2495 ** (0.1257)
σ_{EC}	2.2312 *** (0.3263)	2.2713 *** (0.3313)	2.2413 *** (0.3278)	2.2508 *** (0.3281)	2.2711 *** (0.3316)
----- <i>Model fit statistics</i> -----					
No. of Observations	2808	2808	2808	2808	2808
Log Likelihood	-1415.6	-1412.7	-1411.1	-1415.7	-1412.6
AIC	2869.1	2865.3	2864.1	2871.5	2867.1
Pseudo R-squared	0.273	0.274	0.275	0.273	0.274
Adjusted R-squared	0.263	0.264	0.264	0.262	0.263

*, **, *** statistically significant at the 1%, 5% and 10% level. Standard errors in parenthesis.

¹ Carbon Credit Payment through a Carbon Market was used as the base scenario.

Table 3.7 Ben-Akiva and Swait test results

Model 1	Model 2	Probability¹
GE-PWF	Linear probability	0.0041
GE-PWF	TK-PWF	0.0694
GE-PWF	P1-PWF	0.0019
GE-PWF	P2-PWF	0.0414
TK-PWF	Linear probability	0.0143
TK-PWF	P1-PWF	0.0066
TK-PWF	P2-PWF	0.1830
P2-PWF	Linear probability	0.0231
P2-PWF	P1-PWF	0.0105
Linear probability	P1-PWF	0.1221

¹ Probability of incorrectly choosing model 2 given that model 1 is the true model.

The alternative specific constant was negative in all the models and statistically significant in only two of the models (linear probability weighting specification and GE-PWF). Given that the alternative specific constant is associated with the contract alternative, this result could indicate a preference for the *status quo*. An error component was included in the model to control for unobserved variability across individuals. The error component was highly significant in all the models, indicating significant unobserved heterogeneity across respondents.

3.7.1.2.2 Contract attributes

The payment coefficient was positive and statistically significant in all the model versions (Table 3.6). Incentive payment has consistently been identified in the literature as an important factor in the decision to adopt conservation practices (Cooper, 2003; Dupont, 2010; Kurkalova et al., 2006; Lichtenberg, 2004; Ma et al., 2012). While to some farmers the incentive payment may not be the primary motivation for adoption, monetary incentives can ease their transition into a new production system (Reimer and Prokopy, 2014). Incentive payments can cover the cost of the practice, allowing farmers to experiment with conservation practices to determine if these are suitable for their operations. Results from a study of farmers' participation in a cost-sharing program for the adoption of BMP found that a one percent increase in the incentive payment increased participation by 0.23 to 0.25% (Dupont, 2010). It has been also suggested that the lack of benefits from conservation programs, in many cases is, a barrier for participation by adopters and non-adopters alike (Reimer and Prokopy, 2014).

The program coefficient was negative and statistically significant in all models. These results provide evidence indicating a lower likelihood of adoption for the same level of incentive payment if the mechanism through which the incentive payment is offered is a carbon credit program. This result suggests a preference for federal programs over market-based programs. In

a study of farmers' willingness to participate in conservation programs, Ma et al. (2012) found no statistical difference between a conservation incentive program provided through the government and a non-governmental organization. However, the type of program run by the non-governmental organization was not specified in the choice experiment.

A lower willingness to participate in a conservation program that offers incentives through a carbon market could be related to farmers' unfamiliarity with this type of program. Only 14.3% of the farmers in this study had participated or knew someone who had participated in any carbon credit trading program (specifically, the Chicago Climate Exchange). Of these farmers, about one third rated their experience as poor, specifically due to the lack of payment. Similarly, about 30% of the farmers agreed that the payments offered were fairly low. A negative experience with a previously established and failed carbon market could create unfavorable views towards market-based approaches to incentivize conservation adoption. In addition, uncertainty about the development of a GHG federal policy that would create demand for carbon offsets that could lead to the establishment of a robust carbon market may be another important factor affecting farmers' perceptions and willingness to enroll in a carbon credit program. Zeuli and Skees (2000) argued that the risk of non-binding policies being developed is a factor that could affect the development of a carbon market, mainly due to the uncertainty about trading volumes and the price of carbon credits. Being locked into a contract to supply carbon credits in a market without legal binding of credits for potential buyers may be a deterrent to farmers' willingness to participate. In addition, the past history of carbon markets, such as the Chicago Climate Exchange could have colored farmers' views about this potential payment mechanism.

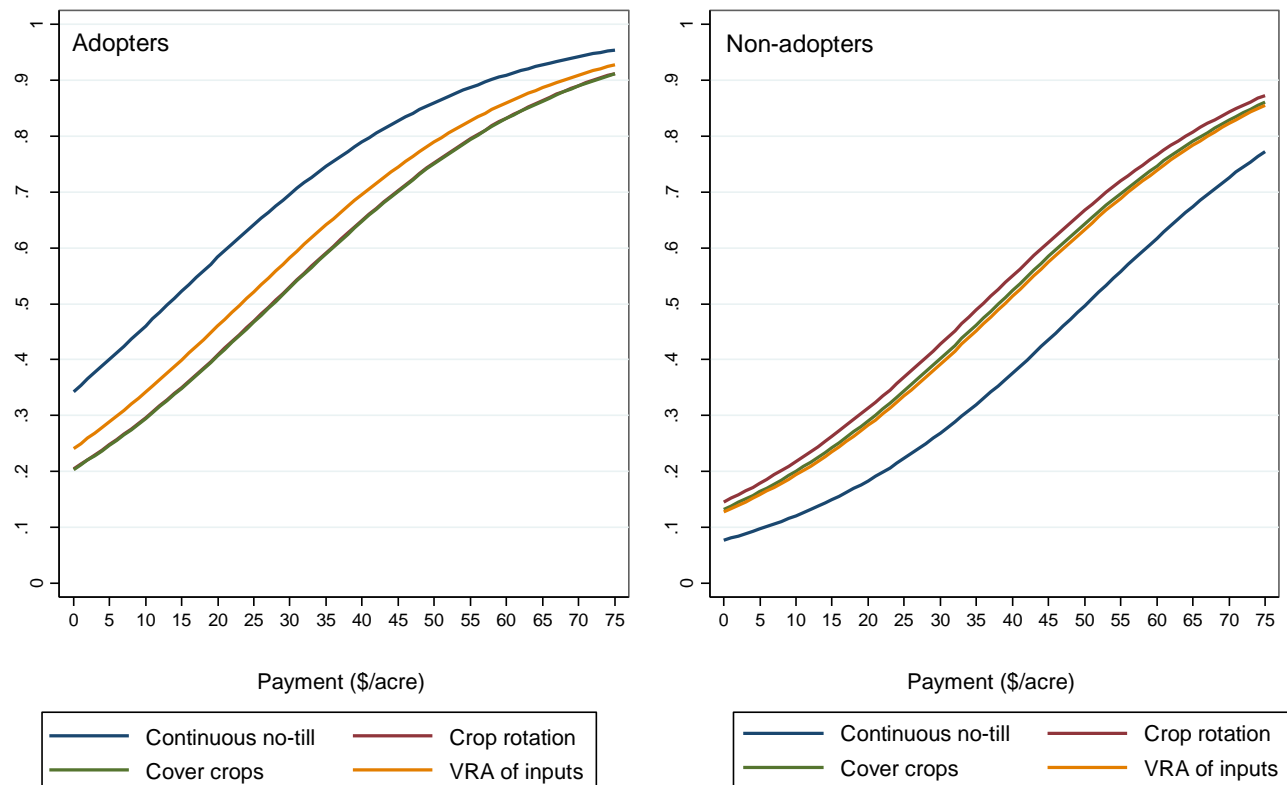
The parameters associated with the four conservation practices were negative and statistically significant in all the models. In agreement with prior expectations, the magnitude of

the utility parameters indicates a lower likelihood of adoption for farmers who have not previously adopted these practices. For farmers who have adopted these practices, the likelihood of enrolling in a conservation program increases as the positive parameters estimated from the interaction between the practices required in the contract and the indicator of previous practice adoption suggest. Figure 3.6 depicts the differences in the likelihood of adoption for each of the conservation practices for adopters and non-adopters. As shown in the graphs, farmers are more likely to enter into a five year contract if they have previously adopted the practice. This difference is more significant for continuous no-till, where for each level of incentive payment, non-adopters are less likely to adopt continuous no-till than any other practice, but for the same level of incentive, adopters of no-till are more likely than adopters of the other practices to enter into the contract.

The parameters for low and medium off-farm environmental benefits were negative and statistically significant, indicating that farmers were less likely to adopt contracts with lower off-farm environmental benefits. Consistent with previous research, this finding suggests that farmers care for the environmental impacts of their practices, not only at the farm level, but also off the farm. In a study of farmers' participation in U.S. Farm Bill Conservation Programs, Reimer and Prokopy (2014) found that off-farm environmental benefit was one of the main drivers of program participation. They also found that awareness of external environmental benefits was an attitude that characterized the highest adopters (adopters of numerous conservation practices). In addition, their results indicated that on-farm environmental benefits and financial benefits were likewise important to those farmers who cared about external environmental impacts. A study by Ma et al. (2012) found that a higher environmental performance increased farmers' likelihood to consider entering into a conservation program,

however, farmers were less likely to enroll land in these programs potentially due to the higher costs associated with higher conservation intensity. An application that stems from this result is the importance of stressing the benefits from conservation not only on-farm but also off-farm to encourage higher levels of conservation adoption. Based on the results of a study of carbon offset program for the adoption of no-till and permanent covers, it has been suggested that incentive payments coupled with farmers' better understanding of the benefits from adopting these practices could encourage greater adoption levels (Morand and Thomassin, 2005).

Figure 3.8 Probability of adoption for each practice under varying incentive payments

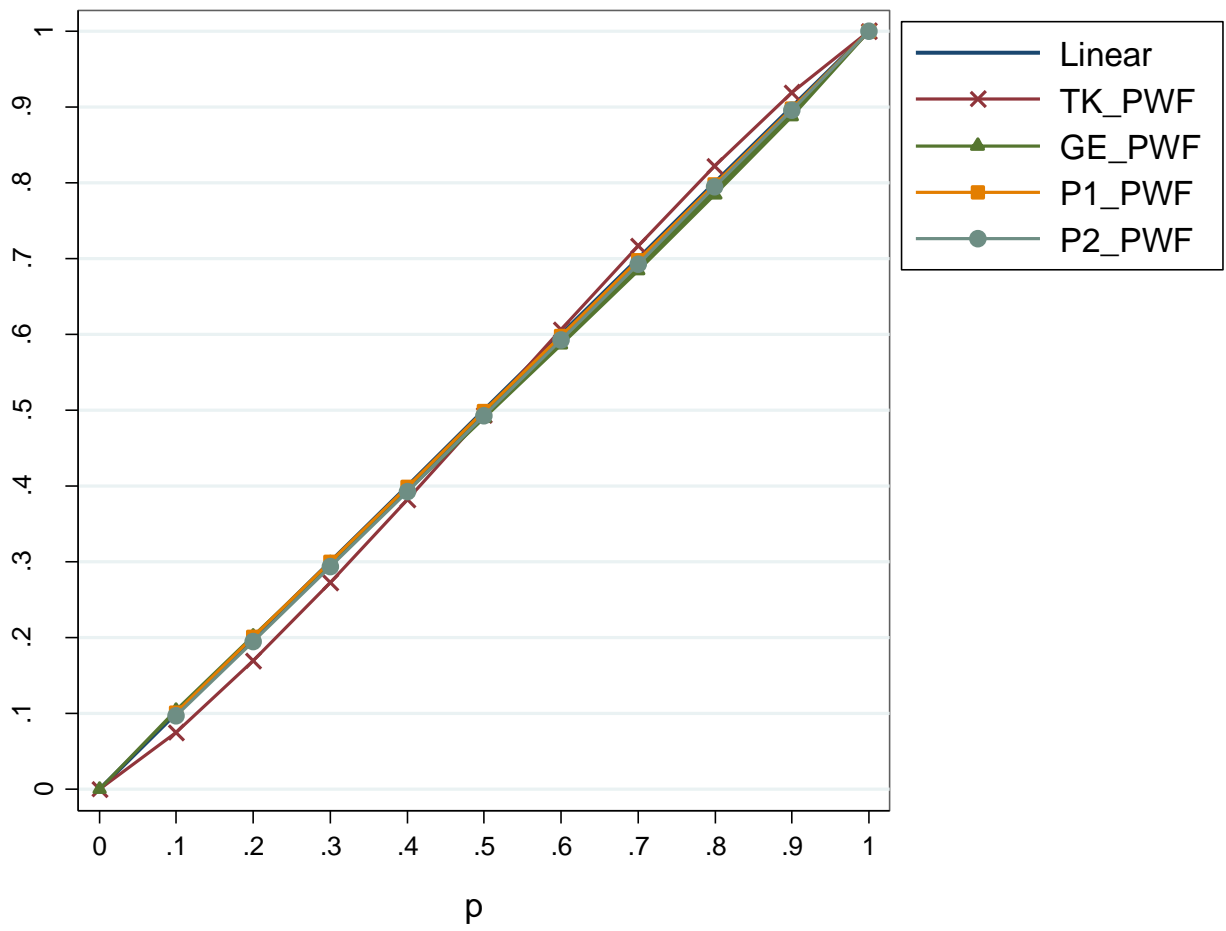


Note: Probabilities estimated assuming high off-farm benefits, mean values for changes in net returns, and a federal program.

3.7.1.2.3 Probability weights, risk attitude, and risk premium

Results corresponding to the probability weights showed minimal transformation of probabilities into decision weights. While the probability weighing function parameters were statistically significant, the results suggest little use of subjective judgments of original probabilities when assessing risk. This reveals limited use of heuristics, that is, the use of previous experience and/or current knowledge about the likelihood of net returns outcomes. Probability weighting responses are illustrated in Figure 3.9. The direction of the GE-PWF and P1-PWF models showed a behavior consistent with overweighting of low probabilities and underweighting of large probabilities, while TK-PWF suggests underweighting of low probabilities and overweighting of large probabilities. Both, overweighting (Kahneman and Tversky, 1979; Lattimore et al., 1992; Prelec, 1998; Tversky and Kahneman, 1992), and underweighting of low probabilities have been found in empirical applications (Humphrey and Verschoor, 2004; Roberts et al., 2008). However, as discussed above, there is minimal transformation of original probabilities in this study. The lines are nearly flat and virtually undistinguishable from the linear specification, as seen in Figure 3.9.

Figure 3.9 Probability weighing functions



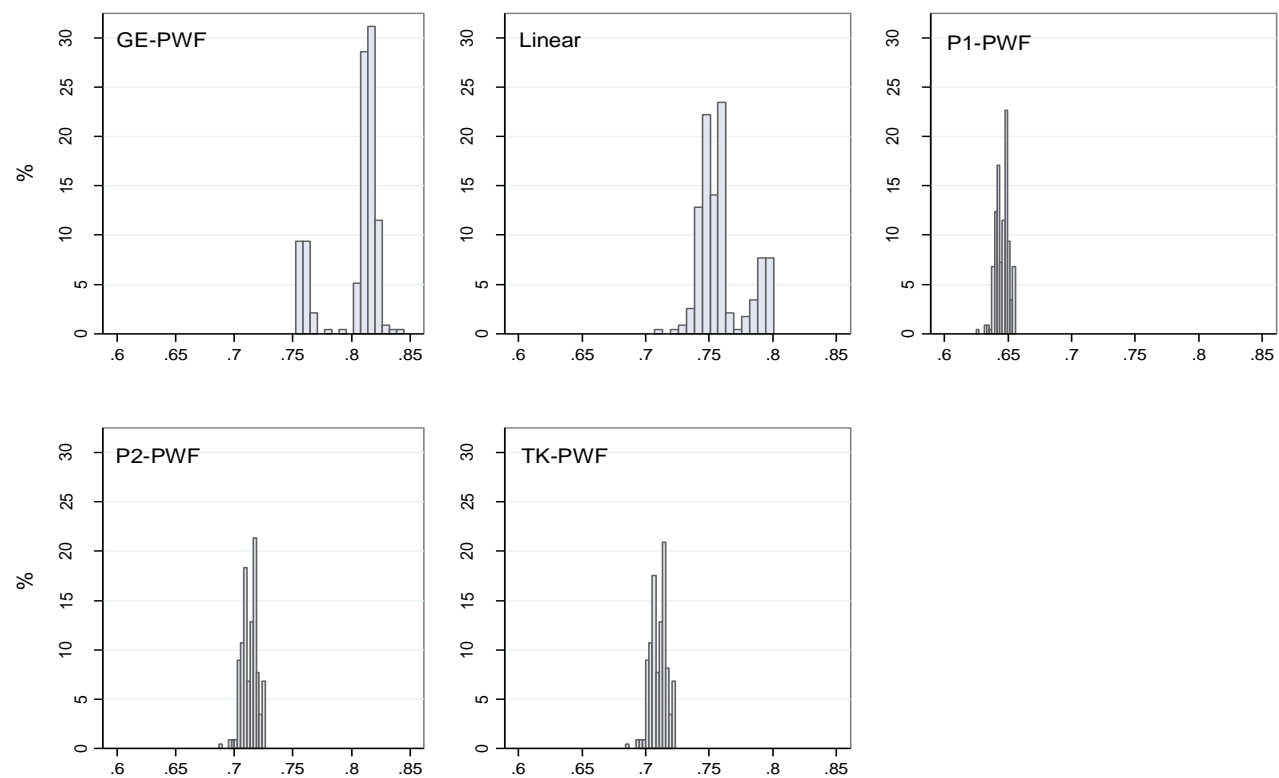
Subjective probabilities could reflect people's perception of uncertainty (Anderson and Dillon, 1992) and aversion to risk as certain outcomes are underweighted, revealing some level of pessimism (Lattimore et al., 1992). For example, consider the probability associated with no changes in net returns. While it was the most certain outcome in each choice set (with a probability of occurrence ranging from 50-80%), it was slightly underweighted. In addition, no strong evidence of prospect pessimism was found as the sum of the probabilities was close to one in all the models (when the sum of the weights is less than one, this is referred to as prospect pessimism (Lattimore et al., 1992). However, it is important to note that, as evidence in the psychological literature suggest, the context and format in which the probabilities are presented during the experiments affects respondents' transformation of probabilities and assessment of risk (Vischers et al., 2009).

The parameters associated with the expected utility of net returns (β_r) was positive in all models but only statistically significant in the linear probability weighting specification and GE-PWF models (Table 3.6). A positive parameter indicates that farmers are more likely to enter into a conservation contract as the value they place on net returns increases. However, the insignificance of the parameter may indicate that the risk associated with the contract and farmers' assessment of uncertainty through probability weights could have a greater effect on farmers' likelihood of entering into the contract than the value they place on the actual outcome.

The constant parameter of risk attitude towards net returns was positive and statistically significant across all models (Table 3.6). Risk attitude parameters corresponding to $\alpha > 0$ indicate risk aversion. In this study, regional variables were not found to significantly affect farmers' level of risk aversion. Farm size as measured by acres was found to be positive and statistically significant in the GE-PWF model, indicating that farmers with larger farms are more

likely to exhibit higher risk aversion. This could be associated with the fact that more acres under the contract could represent a larger potential change in and impact on total net returns. The distributions of the predicted risk attitude parameter for each model specification are depicted in Figure 3.10. It can be seen from this graph that the risk parameters have little dispersion; this is due to the small effect of regional and farm size characteristics. It can also be noted that the predicted level of risk aversion varies across model specifications, with the linear probability specification and the GE-PWF models having more dispersion and revealed risk attitude. It is expected that risk attitudes would fluctuate according to the model used, as these have different underlying behavioral assumptions. It is important thus, to identify the model that best suits the data. Risk aversion parameters found in agriculture-related literature differ depending on the model used and the context of the study. However, most studies agree that, in general, farmers exhibit risk aversion. For some risk aversion estimates in previous studies see (Kumbhakar, 2002; Pennings and Garcia, 2001; Saha et al., 1994).

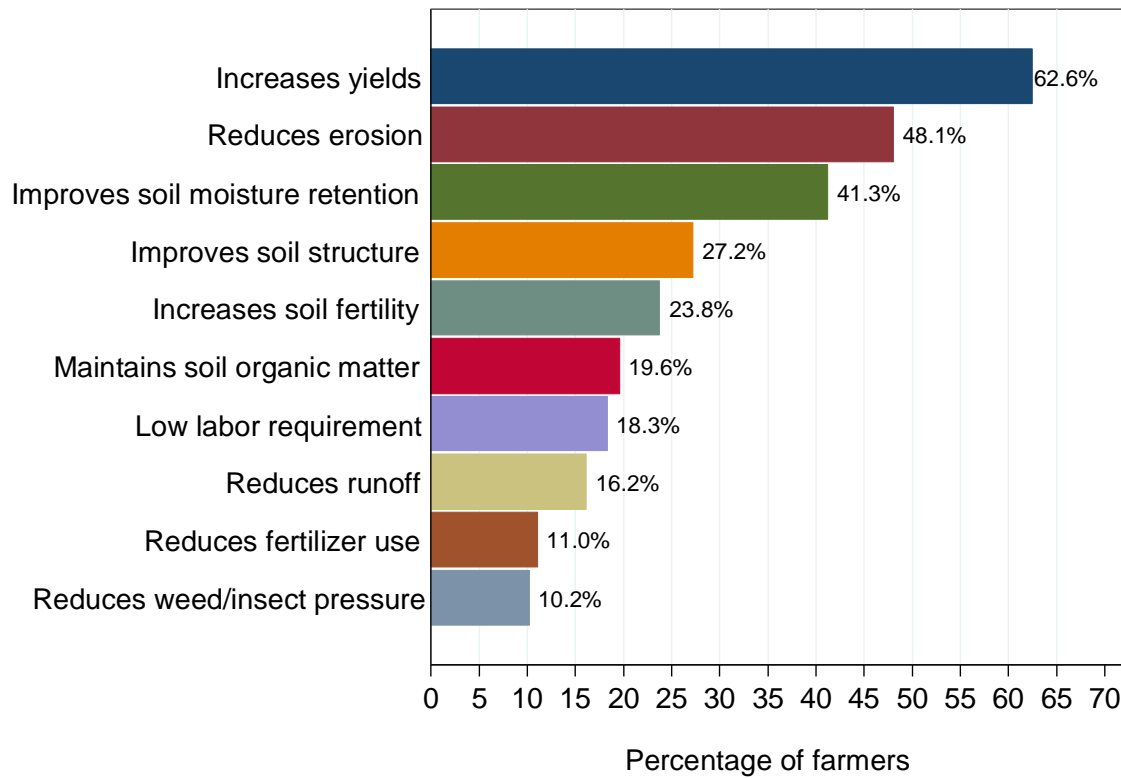
Figure 3.10 Distribution of predicted risk attitude parameters



The risk attitude parameters estimated in this study was relatively small, indicating modest risk aversion. However, risk attitude is context specific (MacCrimmon and Wehrung, 1990). In numerous studies, individuals' risk attitude is elicited using money lotteries. When assessing risk using lottery ticket experiments, responses may represent risk attitudes for extreme events. Nonetheless, issues in agricultural production (e.g. yields, prices) are mainly associated with non-extreme probabilities (Just, 2003). In this study, farmers were presented with a situation where deviations from their expected returns could occur as a result of their decision to enter into a conservation contract. In this scenario, farmers may behave as to prevent losses, especially if adopting these practices is not considered a production priority.

It has also been suggested that risk may be related to outcome expectations, whereby expectations of a better outcome could also influence people's perception of risk (March and Shapira, 1987; Sitkin and Pablo, 1992). Commonly, farmers adopt practices if they receive a private benefit (e.g. profit improvements through increasing yield or cost reductions). If farmers expect to improve their income streams when adopting conservation practices, then an outcome with lower or unchanged net returns may be perceived as an undesirable outcome. For example, 62% of the farmers in this study reported that they would not adopt conservation practices if these failed to improve net farm income. In addition, further analysis of the data reported by these farmers (see Figure 3.11) revealed that increases in yields is the factor most desired in a conservation practice (ranked as the top three benefits by 62.2% of the farmers), above both soil erosion reduction (48.1%) and soil moisture retention (41.3%). Thus, it is plausible that farmers have higher expectations for net returns under conservation.

Figure 3.11 Benefits from conservation practices selected by farmers as the three most important factors



Another factor affecting risk perception is contract restrictiveness. Contract restrictiveness seems to be a major factor in farmers' decision to not enter into a conservation contract. Contract restrictiveness was listed by 34.8% of the farmers as one of the top three reasons for opting out in the stated choice experiment (Figure 3.11). Contracts could potentially limit farmers' ability to respond and adjust their cropping systems to varying weather and market conditions. As De Pinto, Magalhaes, and Ringler (2010) suggest, being locked into a contract with certain practices increases a farmer's vulnerability "to shocks and economic fluctuations". Ma et al. (2012) found that the type of conservation program and the restrictions of the program affect farmers' experience with these programs, influencing their willingness to adopt conservation contracts. Risk from restrictions imposed by a conservation contract could have a larger effect if farmers perceive that under a five year contract, their decision could have consequences that extend into the long-term. As Just (2003) pointed out, long-term changes pose a greater risk to farmers. Zeuli and Skees (2000) also note that the risk that stems from this type of contract, specifically carbon contracts, is the irreversibility of the decision. Some farmers may be less willing to commit to the contract if they have to bear risk for an extended period of time.

As previously discussed, there are different factors affecting farmer's attitude towards risk and in some cases gains in net returns are not sufficient to induce farmers' adoption of certain agricultural practices. In a study of the adoption cost of conservation tillage, Kurkalova, Kling, and Zhao (2006) found that the incentive to induce adoption was higher than the gains in net returns from the adoption of conservation tillage. The premium for the adoption of conservation practices could be the result of aversion to risk and sunk costs (Kurkalova et al., 2006). However if not accounted for directly, the effect of sunk costs could be revealed in farmers' risk attitudes (Ridier et al., 2012). Some of these sunk costs could include the cost of

machinery ownership. In this study, results also indicated that equipment cost was an important consideration affecting farmers' choices in the experiment.

Risk premiums for the adoption of the conservation contract estimated using the regression results are reported in Table 3.8 for the different attribute specific extended expected utility models. There are differences in the resulting measures of risk premiums across the different probability weighting specifications. From the results, it is also apparent that the use of probability decision weights increases the estimated level of risk, taking into account farmers' subjective interpretation of the presented probability distributions and preferences. As shown in Table 3.8, the premium obtained with the linear probability weighting specification is lower compared to the estimates obtained with the nonlinear weights (TK-PWF, GE-PWF, P1-PWF, and P2-PWF). The risk premium obtained when using probability weights ranged from 3.56% to 4.36% of net returns per acre for the preferred models (GE-PWF, TK-PWF, and P2-PWF).

The risk premium is the cost from risk bearing and in this application is found to be moderate. Results suggest that in order for farmers to enter into the contract, they require on average 3.56% to 4.36% of their current net returns as a payment for bearing the risk associated with the contract. Including subjective probability introduces farmers' personal judgment/beliefs of how likely net returns outcomes are to occur, which could also reflect how optimistic or pessimistic farmers' expectations are. In this study, subjective probabilities did not reveal strong pessimism in terms of the expectation of outcome occurrences. When perceptions about the probabilities of outcomes are largely pessimistic, this can result in a higher revealed level of risk. Nonetheless, while transformation of probabilities were not large, the effect from using probability weights was significant, as differences in risk premium estimates when compared to using a linear probability suggest. Since the models with probability weighting specifications

were preferred over the model with original probabilities, this suggests that it is important to evaluate respondents' subjective probabilities; otherwise, estimates of risk perceptions could be underestimated.

Table 3.8 Risk premium estimates

	Risk premium
Linear probability	0.25%
TK-PWF	3.56%
GE-PWF	4.36%
P1-PWF	0.15%
P2-PWF	3.90%

Percentage levels are relative to the level of net returns. For example, the risk premium for the TK-PWF is 3.56% of a farmer's net return.

3.7.2 Marginal Willingness to Accept

Estimates of marginal willingness to accept (mWTA) per acre for the contract attributes are reported in Table 3.9. The range of mWTA estimates across farmers was also reported. Estimates of mWTA were estimated as the ratio of the marginal utility of the contract attributes to the marginal utility of incentive payment, i.e. $\beta_{attribute}/\beta_{pay}$. Estimates of willingness to accept for farmers, who have already adopted conservation practices, were adjusted using the estimates associated with previous adoption. For example, the mWTA for farmers who had not adopted continuous no-till was estimated as $\beta_{nt}NT_j/\beta_{pay}$ and as $(\beta_{nt}NT_j + \beta_{nt_sq}NT_j \times NT_{SQ})/\beta_{pay}$ for farmers who were using continuous no-till. Asymptotic standard errors were estimated using the delta method (Greene, 2012). As can be observed in Table 3.9, mWTA estimates are very consistent across the different model specifications, with estimates from the mean-standard deviation model differing, but only slightly, from the estimates from the attribute specific extended expected utility models. The mWTA estimates for the mean-standard deviation approach estimated using random parameters logit are shown in Figure B.1, in the Appendix. From these graphs, it can be seen that significant variability exists at the individual level.

3.7.2.1 mWTA for conservation practices

The mWTA estimates for the conservation practices (no-till, cover crops, conservation crop rotation and VRA of inputs) represent the per acre payment amount farmers require in order to adopt these practices. The mWTA for the conservation practices was estimated separately for adopters and non-adopters. Some of the factors that could affect the mWTA estimates for the conservation practices are opportunity cost of adopting these practices in comparison with alternative production methods and sunk costs that could include investment in human capital

and/or equipment ownership (Kurkalova et al., 2006). The cost of the practice is also an important factor in the adoption of conservation practices (Lichtenberg, 2004). Some studies have estimated the level of incentive necessary to encourage adoption for different conservation practices under different arrangements (Cooper, 1997; Cooper and Signorello, 2008; Peterson et al., 2012).

The mWTA for farmers who have not adopted continuous no-till was estimated at \$27.45 - \$27.74 per acre across models with different probability weighting specifications (the estimate for the mean-standard deviation approach was \$26.44). In a study conducted in Iowa, Kurkalova, Kling, and Zhao (2006) found that the incentive level to encourage the adoption of conservation tillage in corn was \$4.10/acre and \$6.00/acre in soybeans. Peterson et al. (2012) found a mean estimate of \$9.68 for continuous no-till and \$4.78 for rotational no-till. Kurkalova, Kling, and Zhao (2006) found that farmers' premium for the adoption of conservation tillage in corn or soybeans represented ~13% of farmers' expected returns under conventional tillage and for other crops it represented ~62%. Large willingness to accept estimates in the present study could be the result of the requirement that no-till would be continued over the five years of the contract, without room for soil disturbance if needed (as seen by the farmer). It was been suggested that some no-till farmers may till the ground in response to economic or seasonal drivers (Llewellyn et al., 2012).

Table 3.9 Farmers' marginal willingness to accept (\$/acre)

	Mean-SD	Linear probability	TK-PWF	GE-PWF (Best model)	P1-PWF	P2-PWF
<i>Estimates for non-adopters</i>						
Continuous No-till	-26.44 (3.45)*** [-33.22, -19.65]	-27.73 (3.50)*** [-34.62, -20.84]	-27.65 (3.49)*** [-34.53, -20.77]	-27.44 (3.49)*** [-34.33, -20.57]	-27.74 (3.50)*** [-34.63, -20.85]	-27.64 (3.49)*** [-34.51, -20.76]
Crop Rotation	-14.28 (3.28)*** [-20.73, -7.84]	-13.26 (3.29)*** [-19.73, -6.78]	-13.28 (3.29)*** [-19.75, -6.80]	-13.19 (3.28)*** [-19.67, -6.70]	-13.44 (3.29)*** [-19.91, -6.96]	-13.29 (3.29)*** [-19.78, -6.80]
Cover Crops	-15.42 (2.60)*** [-20.52, -10.32]	-15.22 (2.59)*** [-20.33, -10.11]	-15.45 (2.59)*** [-20.55, -10.34]	-15.22 (2.59)*** [-20.33, -10.11]	-15.31 (2.59)*** [-20.42, -10.2]	-15.47 (2.59)*** [-20.58, -10.36]
VRA of inputs	-17.43 (2.50)*** [-22.34, -12.52]	-16.19 (2.46)*** [-21.04, -11.33]	-16.28 (2.46)*** [-21.13, -11.43]	-16.36 (2.46)*** [-21.22, -11.51]	-16.19 (2.46)*** [-21.04, -11.33]	-16.29 (2.46)*** [-21.14, -11.44]
<i>Estimates for adopters</i>						
Continuous No-till	9.64 (2.55)*** [4.64, 14.65]	9.39 (2.54)*** [4.39, 14.39]	9.44 (2.53)*** [4.45, 14.42]	9.51 (2.54)*** [4.52, 14.51]	9.43 (2.54)*** [4.44, 14.43]	9.44 (2.53)*** [4.46, 14.43]
Crop Rotation	-5.00 (2.55)** [-10.01, 0.001]	-5.06 (2.53)** [-10.05, -0.08]	-4.88 (2.53)* [-9.86, 0.09]	-5.04 (2.53)* [-10.02, 0.05]	-5.04 (2.53)** [-10.02, -0.05]	-4.89 (2.53)* [-9.87, 0.09]
Cover Crops	-4.83 (3.33) [-11.36, 1.71]	-5.15 (3.35) [-11.76, 1.46]	-5.04 (3.35) [-11.64, 1.57]	-5.21 (3.36) [-11.82, 1.40]	-4.98 (3.35) [-11.58, 1.62]	-5.01 (3.36) [-11.62, 1.61]
VRA of inputs	-0.26 (3.62) [-6.85, 7.38]	-0.57 (3.63) [-7.71, 6.58]	-0.61 (3.62) [-7.74, 6.51]	-0.52 (3.62) [-7.66, 6.62]	-0.63 (3.62) [-7.77, 6.51]	-0.62 (3.62) [-7.74, 6.51]
<i>Estimates for other attributes</i>						
Incentive Program ¹	-5.15 (2.11)** [-9.30, -1.00]	-5.09 (2.09)** [-9.22, -0.97]	-4.99 (2.09)** [-9.10, -0.88]	-5.02 (2.09)** [-9.14, -0.90]	-5.09 (2.09)** [-9.21, -0.97]	-4.99 (2.09)** [-9.10, -0.88]
Low off-farm Env. Benefits	-7.86 (2.60)*** [-12.98, -2.75]	-7.42 (2.56)*** [-12.47, -2.38]	-7.44 (2.55)*** [-12.48, -2.41]	-7.63 (2.56)*** [-12.67, -2.58]	-7.43 (2.56)*** [-12.46, -2.39]	-7.44 (2.55)*** [-12.47, -2.40]
Medium off-farm Env. Benefits	-5.18 (2.58)** [-10.24, -0.12]	-4.89 (2.55)* [-9.92, 0.15]	-5.06 (2.55)** [-10.08, -0.03]	-5.24 (2.56)** [-10.28, -0.20]	-4.90 (2.55)* [-9.93, 0.13]	-5.05 (2.55)** [-10.08, -0.03]

*, **, *** statistically significant at the 1%, 5% and 10% level.

Standard errors in parenthesis. Standard errors were estimated using the Delta method. Lower and upper estimates across farmers in brackets.

¹ Carbon Credit Payment through a Carbon Market was used as the base scenario.

For adopters of continuous no-till, the results in this study suggest that they would be willing to pay around \$9.39 - \$9.51 to keep using continuous no-till. This result may be related to sunk costs and irreversibility, particularly equipment ownership and human capital investment. These farmers may have already incurred the required investment to establish the practice on their farms. In addition, farmers may be willing to pay as a result of the private benefits obtained (e.g. yield benefits, soil quality, etc.). A similar conclusion was reached by Cooper (1997) regarding conservation tillage in Iowa. Chouinard et al. (2008) also found evidence suggesting that farmers are willing to pay for stewardship. Specifically, they estimated that farmers were willing to pay \$4.52/acre (estimated as forgone income). This result may also shed some light on the additionality to enrollment in conservation practices. It is apparent from this result that some farmers would adopt these practices in the absence of incentive payments. However, with low incentive payments, new adopters are less likely to be added. In a study of additionality from enrollment in federal programs in Ohio, Mezzatesta, Newburn, and Woodward (2013) found low levels of additionality for conservation tillage (19%), while additionality for cover crops was around 90%.

The mWTA for non-adopters of conservation crop rotation ranged from \$13.19 to \$13.44 across probability weighting specification, and \$14.28 for the mean-standard deviation approach. The estimate for adopters was around \$5 per acre, but the estimate was not statistically significant. The mWTA estimated for cover crops ranged from \$15.22 to \$15.47/acre across all models. This estimate is lower than expected, considering the costs of planting cover crops and farmers' lack of experience with this practice. Singer, Nusser, and Alf (2007) estimated that on average farmers in the U.S. Corn Belt required about \$23 per acre to induce the adoption of cover crops. The estimated mWTA for VRA of inputs ranged from \$16.29 to \$16.36 across the

models with embedded expected utility. Farmers may be reluctant to adopt VRA technologies and may require a higher payment if they perceive these technologies as not being suitable for their operation and if they perceive they have relatively homogenous land (Hudson and Hite, 2003). In addition, given the complexity of this practice, the lack of knowledge may deter adoption, especially for farmers who are not first-time adopters (Batte, 2000; Lamb et al., 2008).

3.7.2.2 mWTA for other contract attributes

The mWTA estimates for the incentive program ranged from \$4.99 to \$5.10/acre in Table 3.9. This result indicates that farmers require an additional payment if the channel through which the conservation program provides and administers the incentive payment is a carbon market. The lack of farmers' awareness of this type of program, the lack of policies for the creation of a binding carbon market, and negative experiences with previous carbon markets may all explain this result. From the sample of farmers who previously participated in a carbon trading scheme, it seems likely that the low payments offered attracted mainly farmers who had already adopted conservation tillage, in the absence of any incentive payment. Thus, low incentive payments may result in low levels of additionality, a major component of program effectiveness (Mezzatesta et al., 2013).

Findings in this study also suggest that conservation bundles with lower off-farm environmental benefits require a larger incentive payment when compared to bundles with higher benefits. Farmers require an additional payment of ~\$4.9 to \$7.63/acre if the bundle of practices they are required to adopt under the conservation contract does not deliver high environmental benefits. This result has important implications for the development of conservation programs. It

is important to work towards improving farmers' awareness of the external benefits (social benefits) of their production decisions (Bergtold et al., 2012). With higher benefits from conservation, adoption in the absence of monetary incentives could increase (Mezzatesta, Newburn, and Woodward, 2013). As the results in this study suggest, if farmers recognize the public (social) environmental benefits from the use of conservation on their farms, they may be more willing to enroll in conservation programs, and it may reduce the level of incentive payment required to encourage enrollment and adoption of bundles of conservation practices.

3.8 Conclusion

This study was designed to determine the factors affecting the adoption of conservation practices under a contract. Various factors involved in a conservation contract were analyzed, the risk of net returns, practices required under the contract, the type of conservation program, and the off-site benefits from the program.

The results in this study suggest that the incentive payment required for farmers who have adopted conservation practices is significantly lower than the necessary payment for non-adopters (farmers who are currently not using the practice). It is possible that if incentive payments are too low, programs may be more attractive to farmers who have already adopted these practices, reducing the potential additionality and associated benefits from these programs. While it is important to encourage adopters to maintain and manage existing conservation practices, for a program to be economically efficient, additional land should be put into conservation at the least cost. As the results in this study suggest, some farmers would adopt in field conservation practices in the absence of incentive payments. In the case of continuous no-

till, adopters may be willing to pay to continue using this practice. This result could indicate that these adopters perceive private benefits from the use of this practice. The experience of farmers who are willing to pay to continue using a practice could be leveraged by extension agencies and conservation programs when promoting the benefits from conservation.

The results in this study also suggest that farmers prefer federally-run programs over market based carbon programs. Given that a limited number of farmers are aware of the mechanism under which carbon offset programs work and that some of the farmers who previously participated in a carbon trading program had negative experiences, it is important to consider these factors if efforts for the establishment of a carbon market are to take place in the future. Farmers may require a premium if incentives are offered through a carbon market, and if incentives payments are low, mainly farmers who have already adopted the practices may be attracted, resulting in low additionality to enrollment in such programs. More importantly, policies are to be in place if a carbon market is to be established. If a binding market exists and public trust in the programs increases, farmers' willingness to participate could be higher. In addition, findings in this study suggest that views regarding the off-farm benefits from agricultural conservation may have an important effect in farmers' willingness to participate in conservation programs and the incentive required under adoption. Hence, education about the societal benefits of on-farm conservation may be an important element to increase the effectiveness of conservation programs.

This study assessed the effect of risk on the adoption and intensification of conservation on the farm by evaluating the effect of the nonlinearity of expected utility for net returns and by including farmers' subjective assessment of probabilities. This method allowed for the estimation of the marginal utility from stochastic net returns and a parameter that measures farmers' risk

attitude towards variability in net returns. In this study, farmers were found to exhibit risk aversion and to moderately use subjective probabilities when evaluating risk of net returns under a conservation contract. Together, these results showed that risk exposure has a significant effect on the adoption of conservation practices. Net returns are stochastic (in part due to the variability in yields), and the distribution of potential outcomes affects farmers' willingness to use conservation programs that may result in changes in their expected returns. These results offer some insight into the importance of considering uncertainty in outcomes when designing incentive programs and extension programs to encourage the adoption of conservation systems (Isik and Yang, 2004).

The results in this study provide important information for extension applications. As some studies have previously suggested, it is important to provide farmers with the range of potential outcomes when promoting new technologies (Ghadim et al., 2005). As farmers are informed about the impact of these technologies in the first years of adoption, efforts can focus on providing farmers with tools to improve their probability of obtaining favorable outcomes to reduce their perception of uncertainty and the effect of perceived risk on the decision to implement and intensify conservation on their farms.

While this study did not directly measure the effect of contract length, further analysis of farmers' responses indicated its negative effect. Farmers reported that the inflexibility of the contract was the main reason for opting out on a contract option in the stated choice experiment. Longer contracts can increase the risk for farmers. Given the dynamics in commodity markets and the development of new technologies, it becomes difficult for farmers to anticipate what will happen in five years (Cattaneo, 2003). Shorter and more flexible contracts may increase farmers' participation in conservation contracts and may reduce the risk of defaulting or withdrawing

from the contract (Cattaneo, 2003). Knowing the potential risk and what incentives farmers may require to reduce potential risks introduced to the farm would ensure that practices, once adopted, are not discontinued.

Previous research findings have indicated that withdrawals from conservation contracts were more likely to occur during the first years of implementation (Cattaneo, 2003). This indicates that there is gap between farmers' expectations and the reality when adopting conservation practices. When expectations are not met, then conservation practices may be unadopted. Thus, conservation education may be the most important factor when promoting conservation programs. It is important that farmers have realistic expectations about the benefits of the practices and how to manage them to obtain better results. A better understanding about the practices and how to manage them to reduce risk, the program mechanism, and the on-farm and off-farm benefits from using conservation may reduce the incentive needed to encourage adoption and may increase the effectiveness of conservation programs.

3.9 Limitations and future research

There are some limitations to this study that need to be acknowledged. This study does not make distinction among the crops for which the practices in the contract had to be implemented, and as findings in previous research suggest, the adoption premium may be vary across different crops (Kurkalova, Kling, and Zhao, 2006). Thus, the incentive payment estimated may be interpreted as a general estimate of the incentive required for the main crops grown in the studied region. In addition, the scope of this study was limited in terms of the sample of farmers studied. The sample of farmers surveyed was medium to large farmers in Kansas who were part of the same

farm management association. Thus, the extrapolation of results to the farmers in the Great Plains of the U.S. and beyond needs to be done with that in mind.

Notwithstanding its limitations, this study offer some important insights into the adoption of conservation practices and how some factors affect farmers' decisions to enroll in conservation contracts. Further work needs to be done to establish how gains and losses affect the risk associated with potential net returns. This can be done by estimating a rank-dependent expected utility model or by adopting cumulative prospect theory in which a different utility is estimated for gains and losses. In addition, to improve the analysis, more net returns outcomes could be included to better trace the curvature of the utility of net returns and the risk attitude parameter. Further research may also explore heterogeneity across individual responses by adopting a random parameters logit model. However, as additional levels of complexities and nonlinearities are included, a larger sample size would be needed.

References

- Adrian, A.M., S.H. Norwood, and P.L. Mask "Producers' perceptions and attitudes toward precision agriculture technologies." *Computers and Electronics in Agriculture* 48 (2005):256-71.
- Aimin, H. "Uncertainty, risk aversion and risk management in agriculture." *Agriculture and Agricultural Science Procedia* 1 (2010):152-6.
- Akter, S., J. Bennett, and M.B. Ward "Climate change scepticism and public support for mitigation: evidence from an Australian choice experiment." *Global Environmental Change* 22 (2012):736-45.
- Anaele, A., and U. Bishnoi "Effects of tillage, weed control method and row spacing on soybean yield and certain soil properties." *Soil and Tillage Research* 23 (1992):333-40.
- Anderson, J.R., and J.L. Dillon *Risk analysis in dryland farming systems* Food & Agriculture Org., 1992.
- Aneja, V.P., W.H. Schlesinger, and J.W. Erisman "Effects of agriculture upon the air quality and climate: Research, policy, and regulations." *Environmental science & technology* 43 (2009):4234-40.
- Antle, J.M., and B. Diagana "Creating incentives for the adoption of sustainable agricultural practices in developing countries: the role of soil carbon sequestration." *American Journal of Agricultural Economics* 85 (2003):1178-84.
- Antle, J., S. Capalbo, S. Mooney, E. Elliott, and K. Paustian "Spatial heterogeneity, contract design, and the efficiency of carbon sequestration policies for agriculture." *Journal of Environmental Economics and Management* 46 (2003):231-50.
- Batte, M.T. "Factors influencing the profitability of precision farming systems." *Journal of Soil and Water Conservation* 55 (2000):12-8.
- Batte, M.T., and M.W. Arnholt "Precision farming adoption and use in Ohio: case studies of six leading-edge adopters." *Computers and Electronics in Agriculture* 38 (2003):125-39.
- Beal, D.J. "Emerging issues in risk management in farm firms." *Review of Marketing and Agricultural Economics* 64 (1996):
- Belknap, J., and W.E. Saupe "Farm family resources and the adoption of no-plow tillage in Southwestern Wisconsin." *North Central Journal of Agricultural Economics* 10 (1988):13-23.
- Ben-Akiva, M.E., and S.R. Lerman *Discrete choice analysis: theory and application to travel demand* MIT press, 1985.

- Ben-Akiva, M., and J. Swait "The Akaike likelihood ratio index." *Transportation Science* 20 (1986):133-6.
- Bergtold, J.S., and J.J. Molnar. "Limited Access to Conservation: Limited- Resource Farmer Participation in the Conservation Security Program in the Southeast." *Journal of Agricultural and Applied Economics* 42(2010): 211-227.
- Bergtold, J.S., P.A. Duffy, D. Hite, and R.L. Raper "Demographic and management factors affecting the adoption and perceived yield benefit of winter cover crops in the southeast." *Journal of Agricultural and Applied Economics* 44 (2012):99-116.
- Bhat, C.R. "Accommodating flexible substitution patterns in multi-dimensional choice modeling: formulation and application to travel mode and departure time choice." *Transportation Research Part B: Methodological* 32 (1998):455-66.
- Biermacher, J.T., B.W. Brorsen, F.M. Epplin, J.B. Solie, and W.R. Raun "The economic potential of precision nitrogen application with wheat based on plant sensing." *Agricultural Economics* 40 (2009):397-407.
- Blanco-Canqui, H., L. Stone, A.J. Schlegel, D. Lyon, M. Vigil, M. Mikha, P. Stahlman, and C. Rice "No-till induced increase in organic carbon reduces maximum bulk density of soils." *Soil Science Society of America Journal* 73 (2009):1871-9.
- Blevins, R., M. Smith, G. Thomas, and W. Frye "Influence of conservation tillage on soil properties." *Journal of Soil and Water Conservation* 38 (1983):301-5.
- Bockus, W., and J. Shroyer "The impact of reduced tillage on soilborne plant pathogens." *Annual Review of Phytopathology* 36 (1998):485-500.
- Brewer, M.J., R.J. Hoard, J.N. Landis, and L.E. Elworth "The case and opportunity for public-supported financial incentives to implement integrated pest management." *Journal of economic entomology* 97 (2004):1782-9.
- Burghart, D.R., T.A. Cameron, and G.R. Gerdes "Valuing publicly sponsored research projects: risks, scenario adjustments, and inattention." *Journal of Risk and Uncertainty* 35 (2007):77-105.
- Campbell, C., F. Selles, G. Lafond, and R. Zentner "Adopting zero tillage management: Impact on soil C and N under long-term crop rotations in a thin Black Chernozem." *Canadian Journal of Soil Science* 81 (2001):139-48.
- Cardina, J., C.P. Herms, and D.J. Doohan "Crop rotation and tillage system effects on weed seedbanks." *Weed Science* 50 (2009): 448-460.
- Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith "Nonpoint pollution of surface waters with phosphorus and nitrogen." *Ecological Applications* 8 (1998):559-68.

- Caswell, M., and D. Zilberman "The choices of irrigation technologies in California." *American Journal of Agricultural Economics* 67 (1985):224-34.
- Cattaneo, A. "The pursuit of efficiency and its unintended consequences: contract withdrawals in the environmental quality incentives program." *Review of Agricultural Economics* 25 (2003):449-69.
- Chan, K., and D. Heenan "The influence of crop rotation on soil structure and soil physical properties under conventional tillage." *Soil and Tillage Research* 37 (1996):113-25.
- Chouinard, H.H., T. Paterson, P.R. Wandschneider, and A.M. Ohler "Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection." *Land Economics* 84 (2008):66-82.
- Claassen, R., A. Cattaneo, and R. Johansson "Cost-effective design of agri-environmental payment programs: US experience in theory and practice." *Ecological Economics* 65 (2008):737-52.
- Clark, A. *Managing cover crops profitably*. DIANE Publishing, 2008.
- Comito, J., J. Wolseth, and L.W. Morton "The State's role in water quality: Soil and Water Conservation District commissioners and the agricultural status quo." *Human organization* 72 (2013):44-54.
- Cooper, J.C. "Combining actual and contingent behavior data to model farmer adoption of water quality protection practices." *Journal of Agricultural and Resource Economics* 22 (1997):30-43.
- "A joint framework for analysis of agri-environmental payment programs." *American Journal of Agricultural Economics* 85 (2003):976-87.
- Cooper, J.C., and R.W. Keim "Incentive payments to encourage farmer adoption of water quality protection practices." *American Journal of Agricultural Economics* 78 (1996):54-64.
- Cooper, J.C., and G. Signorello "Farmer premiums for the voluntary adoption of conservation plans." *Journal of Environmental Planning and Management* 51 (2008):1-14.
- Daniel, J., A. Abaye, M. Alley, C. Adcock, and J. Maitland "Winter annual cover crops in a Virginia no-till cotton production system: II. Cover crop and tillage effects on soil moisture, cotton yield, and cotton quality." *Journal of Cotton Science* 3 (1999):84-91.
- De Pinto, A., M. Magalhaes, and C. Ringler "Potential of carbon markets for small farmers." *IFPRI discussion papers, International Food Policy Research Institute (IFPRI)* 1004 (2010):

- DeJong-Hughes, J., and J. Vetsch "On-farm comparison of conservation tillage systems for corn following soybeans." University of Minnesota Extension (2007). Available online at: <http://purl.umn.edu/48314>
- Derpsch, R., T. Friedrich, A. Kassam, and H. Li "Current status of adoption of no-till farming in the world and some of its main benefits." *International Journal of Agricultural and Biological Engineering* 3 (2010):1-25.
- Dorfman, J.H. "Modeling multiple adoption decisions in a joint framework." *American Journal of Agricultural Economics* 78 (1996):547-57.
- Dupont, D.P. "Cost-Sharing Incentive Programs for Source Water Protection: The Grand River's Rural Water Quality Program." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 58 (2010):481-96.
- Epplin, F.M., T.F. Tice, A.E. Baquet, and S.J. Handke "Impacts of reduced tillage on operating inputs and machinery requirements." *American Journal of Agricultural Economics* 64 (1982):1039-46.
- Ervin, C.A., and D.E. Ervin "Factors affecting the use of soil conservation practices: hypotheses, evidence, and policy implications." *Land Economics* 58 (1982):277-92.
- Espinosa-Goded, M., J. Barreiro-Hurlé, and E. Ruto "What do farmers want from Agri-environmental scheme design? A choice experiment approach." *Journal of Agricultural economics* 61 (2010):259-73.
- Fargione, J.E., T.R. Cooper, D.J. Flaspohler, J. Hill, C. Lehman, D. Tilman, T. McCoy, S. McLeod, E.J. Nelson, and K.S. Oberhauser "Bioenergy and wildlife: threats and opportunities for grassland conservation." *Bioscience* 59 (2009):767-77.
- Fernandez-Cornejo, J., S. Daberkow, and W.D. McBride "Decomposing The Size Effect On The Adoption Of Innovations: agrobiotechnology and precision agriculture." *AgBioForum* 4 (2002):124-236.
- Freeman, J., and C.D. Kolstad "Prescriptive environmental regulations versus market-based incentives." *Moving to Markets in Environmental Regulation: Lessons from Twenty Years of Experience: Lessons from Twenty Years of Experience* (2006):1.
- Fuglie, K.O. "Conservation tillage and pesticide use in the Cornbelt." *Journal of Agricultural and Applied Economics* 31 (1999):133-48.
- Galatowitsch, S.M. "Carbon offsets as ecological restorations." *Restoration Ecology* 17 (2009):563-70.
- Galloway, J.N., A.R. Townsend, J.W. Erisman, M. Bekunda, Z. Cai, J.R. Freney, L.A. Martinelli, S.P. Seitzinger, and M.A. Sutton "Transformation of the nitrogen cycle: recent trends, questions, and potential solutions." *Science (New York, N.Y.)* 320 (2008):889-92.

- Ghadim, A.K.A., D.J. Pannell, and M.P. Burton "Risk, uncertainty, and learning in adoption of a crop innovation." *Agricultural Economics* 33 (2005):1-9.
- Gill-Austern, D. "The impact of rising corn prices on the conservation reserve program: an empirical model." *Undergraduate Economic Review* 7 (2011):22.
- Glenk, K., and S. Colombo "How sure can you be? A framework for considering delivery uncertainty in benefit assessments based on stated preference methods." *Journal of Agricultural Economics* 62 (2011):25-46.
- "Modelling outcome-related risk in choice experiments." *Australian Journal of Agricultural and Resource Economics* 57 (2013):559-78.
- Golden, B., J. Bergtold, M. Boland, K. Dhuyvetter, T. Kastens, J. Peterson, and S. Staggenborg "A Comparison of Select Cost-Benefit Studies on the Impacts of HR 2454 on the Agriculture Sector of the Economy." *AgManager.info* (2009):
- Goldstein, W.M., and H.J. Einhorn "Expression theory and the preference reversal phenomena." *Psychological review* 94 (1987):236.
- Gonzalez, R., and G. Wu "On the shape of the probability weighting function." *Cognitive Psychology* 38 (1999):129-66.
- González-Ramírez, J., C.L. Kling, and A. Valcu "An overview of carbon offsets from agriculture." *Annual Review of Resource Economics* 4 (2012):145-60.
- Grandy, A., G. Robertson, and K. Thelen "Do productivity and environmental trade-offs justify periodically cultivating no-till cropping systems?" *Agronomy Journal* 98 (2006):1377-83.
- Greene, W.H. *Econometric Analysis*, 7th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall., 2012.
- Greiner, R., L. Patterson, and O. Miller "Motivations, risk perceptions and adoption of conservation practices by farmers." *Agricultural Systems* 99 (2009):86-104.
- Hamilton, K., M. Sjardin, A. Shapiro, and T. Marcello "Fortifying the foundation: state of the voluntary carbon markets 2009." *Fortifying the foundation: state of the voluntary carbon markets 2009* (2009): Ecosystem Market Place and New Carbon Finance.
- Hardaker, J.B., R.B. Huirne, J.R. Anderson, and G. Lien *Coping with risk in agriculture*. CABI publishing, 2004.
- Havlin, J., D. Kissel, L. Maddux, M. Claassen, and J. Long "Crop rotation and tillage effects on soil organic carbon and nitrogen." *Soil Science Society of America Journal* 54 (1990):448-52.

- Heer, W.F., and E.G. Krenzer Jr "Soil water availability for spring growth of winter wheat *Triticum aestivum* L. as influenced by early growth and tillage." *Soil and Tillage Research* 14 (1989):185-96.
- Helmets, G.A., M.R. Langemeier, and J. Atwood "An economic analysis of alternative cropping systems for east-central Nebraska." *American Journal of Alternative Agriculture* 1 (1986):153-8.
- Hensher, D.A., W.H. Greene, and Z. Li "Embedding risk attitude and decision weights in non-linear logit to accommodate time variability in the value of expected travel time savings." *Transportation Research Part B Methodological* 45 (2011):954-72.
- Hensher, D.A., J.M. Rose, and W.H. Greene *Applied choice analysis: a primer*. Cambridge University Press, 2005.
- Hudson, D., and D. Hite "Producer willingness to pay for precision application technology: Implications for government and the technology industry." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 51 (2003):39-53.
- Humphrey, S.J., and A. Verschoor "The probability weighting function: experimental evidence from Uganda, India and Ethiopia." *Economics Letters* 84 (2004):419-25.
- Isik, M., and W. Yang "An analysis of the effects of uncertainty and irreversibility on farmer participation in the conservation reserve program." *Journal of Agricultural and Resource Economics* 29 (2004):242-59.
- Jaenicke, E.C., D.L. Frechette, and J.A. Larson "Estimating production risk and inefficiency simultaneously: an application to cotton cropping systems." *Journal of Agricultural and Resource Economics* 28 (2003):540-57.
- Johnson, D., S. Ambrose, T. Bassett, M. Bowen, D. Crummey, J. Isaacson, D. Johnson, P. Lamb, M. Saul, and A. Winter-Nelson "Meanings of environmental terms." *Journal of Environmental Quality* 26 (1997):581-9.
- Just, R.E. "Risk research in agricultural economics: opportunities and challenges for the next twenty-five years." *Agricultural Systems* 75 (2003):123-59.
- Kahneman, D., and A. Tversky "Prospect theory: An analysis of decision under risk." *Econometrica: Journal of the Econometric Society* 47 (1979):263-91.
- Kaval, P. "The profitability of alternative cropping systems: a review of the literature." *Journal of Sustainable Agriculture* 23 (2004):47-65.
- Kelley K.W., J.H. Long, and T.C. Todd "Long-term crop rotations affect soybean yield, seed weight, and soil chemical properties." *Field Crops Research* 83(2003): 41–50.

- KFMA. Kansas Farm Management Association. (2015). Available online at: <http://www.agmanager.info/kfma/>
- Khanna M., and D. Zilberman "Incentives, Precision Technology and Environmental Protection." *Ecological Economics* 23 (1997):25–43.
- Kim, S., J.M. Gillespie, and K.P. Paudel "The effect of socioeconomic factors on the adoption of best management practices in beef cattle production." *Journal of Soil and Water Conservation* 60 (2005):111-20.
- Kim, S., and B.E. Dale "Effects of nitrogen fertilizer application on greenhouse gas emissions and economics of corn production." *Environmental science & technology* 42 (2008):6028-33.
- Kladivko, E.J. "Tillage systems and soil ecology." *Soil and Tillage Research* 61 (2001):61-76.
- Kotchen, M.J., and E.T. Mansur "How Stringent Are the US EPA's Proposed Carbon Pollution Standards for New Power Plants?" *Review of Environmental Economics and Policy* (2014):
- Kumbhakar, S.C. "Specification and estimation of production risk, risk preferences and technical efficiency." *American Journal of Agricultural Economics* 84 (2002):8-22.
- Kurkalova, L., C. Kling, and J. Zhao "Green subsidies in agriculture: Estimating the adoption costs of conservation tillage from observed behavior." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 54 (2006):247-67.
- Kushwaha, C., S. Tripathi, and K. Singh "Soil organic matter and water-stable aggregates under different tillage and residue conditions in a tropical dryland agroecosystem." *Applied Soil Ecology* 16 (2001):229-41.
- Lal, R. "Long-term tillage and wheel traffic effects on soil quality for two central Ohio soils." *Journal of Sustainable Agriculture* 14 (1999):67-84.
- Lal, R. "Tillage effects on soil degradation, soil resilience, soil quality, and sustainability." *Soil and Tillage Research* 27 (1993):1-8.
- Lamb, D.W., P. Frazier, and P. Adams "Improving pathways to adoption: Putting the right P's in precision agriculture." *Computers and Electronics in Agriculture* 61 (2008):4-9.
- Lambert, D.M., P. Sullivan, R. Claassen, and L. Foreman "Profiles of US farm households adopting conservation-compatible practices." *Land Use Policy* 24 (2007):72-88.
- Lancaster, K.J. "A new approach to consumer theory." *The journal of political economy* 74 (1966):132-57.

- Larson, J.A., E.C. Jaenicke, R.K. Roberts, and D.D. Tyler "Risk effects of alternative winter cover crop, tillage, and nitrogen fertilization systems in cotton production." *Journal of Agricultural and Applied Economics* 33 (2001a):445-58.
- Larson, J., R. Roberts, E. Jaenicke, and D. Tyler "Profit-maximizing nitrogen fertilization rates for alternative tillage and winter cover systems." *Journal of Cotton Science* 5 (2001b):156-68.
- Lattimore, P.K., J.R. Baker, and A.D. Witte "The influence of probability on risky choice: A parametric examination." *Journal of Economic Behavior & Organization* 17 (1992):377-400.
- Li, Z., and D.A. Hensher "Behavioural implications of preferences, risk attitudes and beliefs in modelling risky travel choice with travel time variability." *Transportation* 40 (2013):505-23.
- Li, Z., D.A. Hensher, and J.M. Rose "Willingness to pay for travel time reliability in passenger transport: a review and some new empirical evidence." *Transportation Research part E: Logistics and Transportation Review* 46 (2010):384-403.
- Li, Z., A. Tirachini, and D.A. Hensher "Embedding risk attitudes in a scheduling model: application to the study of commuting departure time." *Transportation Science* 46 (2012):170-88.
- Lichtenberg, E. "Cost-responsiveness of conservation practice adoption: A revealed preference approach." *Journal of Agricultural and Resource Economics* 29 (2004):420-35.
- Llewellyn, R.S., F.H. D'Emden, and G. Kuehne "Extensive use of no-tillage in grain growing regions of Australia." *Field Crops Research* 132 (2012):204-12.
- Lodhi, M., R. Bilal, and K. Malik "Allelopathy in agroecosystems: wheat phytotoxicity and its possible roles in crop rotation." *Journal of chemical ecology* 13 (1987):1881-91.
- Louviere, J.J., D.A. Hensher, and J.D. Swait *Stated choice methods: analysis and applications*. Cambridge University Press, 2000.
- Lu, Yao-Chi, K. Bradley Watkins, R.T. John, and A. Aref "Cover crops in sustainable food production." *Food Reviews International* 16 (2000):121-157.
- Ma, S., S.M. Swinton, F. Lupi, and C. Jolejole-Foreman "Farmers' Willingness to Participate in Payment-for-Environmental-Services Programmes." *Journal of Agricultural Economics* 63 (2012):604-26.
- MacCrimmon, K.R., and D.A. Wehrung "Characteristics of risk taking executives." *Management Science* 36 (1990):422-35.

- Maddala, G.S. *Limited-dependent and qualitative variables in econometrics*. Cambridge University Press, 1983.
- March, J.G., and Z. Shapira "Managerial perspectives on risk and risk taking." *Management Science* 33 (1987):1404-18.
- Marra, M.C., and G.A. Carlson "The decision to double crop: an application of expected utility theory using Stein's theorem." *American Journal of Agricultural Economics* 72 (1990):337-45.
- Marra, M., D.J. Pannell, and A. Abadi Ghadim "The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?" *Agricultural Systems* 75 (2003):215-34.
- McConkey, B., B. Liang, C. Campbell, D. Curtin, A. Moulin, S. Brandt, and G. Lafond "Crop rotation and tillage impact on carbon sequestration in Canadian prairie soils." *Soil and Tillage Research* 74 (2003):81-90.
- Meisinger, J.J., F.J. Calderon, and D.S. Jenkinson "Soil Nitrogen Budgets." *American Society of Agronomy Monograph Series* 13 (2008):505-562.
- Meyer, J. "Representing risk preferences in expected utility based decision models." *Annals of Operations Research* 176 (2010):179-90.
- Mezzatesta, M., D.A. Newburn, and R.T. Woodward "Additionality and the adoption of farm conservation practices." *Land Economics* 89 (2013):722-42.
- Miglierina A.M., J.O. Iglesias, M.R. Landriscini, J.A. Galantini, and R.A. Rosell "The effects of crop rotation and fertilization on wheat productivity in the Pampean semiarid region of Argentina: 1. Soil physical and chemical properties." *Soil Tillage Research* 53(2000): 129–135.
- Miguez, F.E., and G.A. Bollero "Review of corn yield response under winter cover cropping systems using meta-analytic methods." *Crop Science* 45 (2005):2318-29.
- Morand, H., and P.J. Thomassin "Changes in Quebec Cropping Practices in Response to a Carbon Offset Market: A Simulation." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 53 (2005):403-24.
- Nascente, A.S., Y.C. Li, and C.A.C. Crusciol "Cover crops and no-till effects on physical fractions of soil organic matter." *Soil and Tillage Research* 130 (2013):52-7.
- NRCS - Natural Resources Conservation Systems. "Conservation Stewardship Program - Payment for Performance." (2015a). Available online at:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/financial/csp/?cid=nr143_008316

- NRCS - Natural Resources Conservation Systems.” 2015 KS Practice payment cost data.” (2015b). Available online at: <http://efotg.sc.egov.usda.gov/treemenu.aspx>
- Paustian, K., J. Six, E. Elliott, and H. Hunt "Management options for reducing CO₂ emissions from agricultural soils." *Biogeochemistry* 48 (2000):147-63.
- Pennings, J.M., and P. Garcia "Measuring producers' risk preferences: A global risk-attitude construct." *American Journal of Agricultural Economics* 83 (2001):993-1009.
- Peterson, J.M., C.M. Smith, J.C. Leatherman, N.P. Hendricks, and J.A. Fox "The role of contract attributes in purchasing environmental services from landowners." *Kansas State University, Kansas* (2012):
- Pierce, F.J., and C.W. Rice "Crop rotation and its impact on efficiency of water and nitrogen use." *Cropping strategies for efficient use of water and nitrogen* (1988):21-42.
- Pratt, J.W. "Risk aversion in the small and in the large." *Econometrica: Journal of the Econometric Society* 32 (1964):122-36.
- Prelec, D. "The probability weighting function." *Econometrica* 66 (1998):497-527.
- Rahm, M.R., and W.E. Huffman "The adoption of reduced tillage: the role of human capital and other variables." *American Journal of Agricultural Economics* 66 (1984):405-13.
- Raimbault, B., and T. Vyn "Crop rotation and tillage effects on corn growth and soil structural stability." *Agronomy Journal* 83 (1991):979-85.
- Reicosky, D. C., and F. Forcella “Cover crop and soil quality interactions in agroecosystems.” *Journal of Soil and Water Conservation* 53 (1998):224-229.
- Reimer, A.P., and L.S. Prokopy "Farmer Participation in US Farm Bill Conservation Programs." *Environmental management* 53 (2014):318-32.
- Ribaudo, M., C. Greene, L. Hansen, and D. Hellerstein "Ecosystem services from agriculture: steps for expanding markets." *Ecological Economics* 69 (2010):2085-92.
- Ribera, L.A., F. Hons, and J.W. Richardson "An economic comparison between conventional and no-tillage farming systems in Burleson County, Texas." *Agronomy Journal* 96 (2004):415-24.
- Ridier, A., K. Chaib, and C. Roussy *The adoption of innovative cropping systems under price and production risks: a dynamic model of crop rotation choice*, Feb 2012, Dublin, Ireland. ed2012.
- Robbins, A. "Ecosystem Services Markets." University of Washington College of Forest Resources. (2005). Available online at: <https://digital.lib.washington.edu/researchworks/handle/1773/2244?show=full>

- Roberts, D.C., T.A. Boyer, and J.L. Lusk "Preferences for environmental quality under uncertainty." *Ecological Economics* 66 (2008):584-93.
- Roberts, R. K., B.C. English, and S.B. Mahajanashetti "Evaluating the returns to variable rate nitrogen application." *Journal of Agricultural and Applied Economics* 32 (200):133-143.
- Rodriguez, J.M., J.J. Molnar, R.A. Fazio, E. Sydnor, and M.J. Lowe "Barriers to adoption of sustainable agriculture practices: Change agent perspectives." *Renewable Agriculture and Food Systems* 24 (2009):60-71.
- Rolfe, J., and J. Windle "Including management policy options in discrete choice experiments: a case study of the Great Barrier Reef." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 61 (2013):197-215.
- Roth, G.W. "Crop Rotations and Conservation Tillage". Conservation Tillage Series (1996) 1.
- Ruto, E., and G. Garrod "Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach." *Journal of Environmental Planning and Management* 52 (2009):631-47.
- Saha, A., C.R. Shumway, and H. Talpaz "Joint estimation of risk preference structure and technology using expo-power utility." *American Journal of Agricultural Economics* 76 (1994):173-84.
- Saltiel, J., J.W. Bauder, and S. Palakovich "Adoption of Sustainable Agricultural Practices: Diffusion, Farm Structure, and Profitability1." *Rural Sociology* 59 (1994):333-49.
- SAS Institute Inc., SAS/QC® User's Guide, Version 8, Cary, NC: SAS Institute Inc., 1999. 1994pp.
- Sarrantonio, M., and E. Gallandt "The role of cover crops in North American cropping systems." *Journal of Crop Production* 8 (2003):53-74.
- Sattler, C., and U.J. Nagel "Factors affecting farmers' acceptance of conservation measures—a case study from north-eastern Germany." *Land Use Policy* 27 (2010):70-7.
- Schimmelpfennig, D., and R. Ebel *On the doorstep of the information age: Recent adoption of precision agriculture* US Department of Agriculture, Economic Research Service, 2011.
- Shapiro, B.I., B. Wade Brorsen, and D.H. Doster "Adoption of double-cropping soybeans and wheat." *Southern Journal of Agricultural Economics* 24 (1992):33-.
- Singer, J., S. Nusser, and C. Alf "Are cover crops being used in the US corn belt?" *Journal of Soil and Water Conservation* 62 (2007):353-8.
- Sitkin, S.B., and A.L. Pablo "Reconceptualizing the determinants of risk behavior." *Academy of Management Review* 17 (1992):9-38.

- Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach, and J. Smith "Greenhouse gas mitigation in agriculture." *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 363 (2008):789-813.
- Soil Science Society of America. "Glossary of Soil Science Terms." (2012). Available online at: <https://www.soils.org/publications/soils-glossary#>
- Snapp, S., S. Swinton, R. Labarta, D. Mutch, J. Black, R. Leep, J. Nyiraneza, and K. O'Neil "Evaluating cover crops for benefits, costs and performance within cropping system niches." *Agronomy Journal* 97 (2005):322-32.
- Soule, M.J., A. Tegene, and K.D. Wiebe "Land tenure and the adoption of conservation practices." *American Journal of Agricultural Economics* 82 (2000):993-1005.
- Stott, H.P. "Cumulative prospect theory's functional menagerie." *Journal of Risk and Uncertainty* 32 (2006):101-30.
- Tversky, A., and D. Kahneman "Advances in prospect theory: Cumulative representation of uncertainty." *Journal of Risk and Uncertainty* 5 (1992):297-323.
- Tyner, W., and F. Taheripour "Biofuels, policy options, and their implications: Analyses using partial and general equilibrium approaches." *Journal of Agricultural & Food Industrial Organization* 6 (2008):
- Van Houtven, G., F.R. Johnson, V. Kilambi, and A.B. Hauber "Eliciting benefit-risk preferences and probability-weighted utility using choice-format conjoint analysis." *Medical decision making: an international journal of the Society for Medical Decision Making* 31 (2011):469-80.
- Varner, B.T., F.M. Epplin, and G.L. Strickland "Economics of no-till versus tilled dryland cotton, grain sorghum, and wheat." *Agronomy Journal* 103 (2011):1329-38.
- Vellidis, G., B. Ortiz, J. Beasley, R. Hill, H. Henry, and H. Brannen "Using RTK-based GPS guidance for planting and inverting peanuts." *Precision Agriculture '13* (2013):357-364.
- Veronesi, M., F. Chawla, M. Maurer, and J. Lienert "Climate change and the willingness to pay to reduce ecological and health risks from wastewater flooding in urban centers and the environment." *Ecological Economics* 98 (2014):1-10.
- Vischers, V.H., R.M. Meertens, W.W. Passchier, and N.N. De Vries "Probability information in risk communication: a review of the research literature." *Risk Analysis* 29 (2009):267-87.
- Von Neumann, J., and O. Morgenstern "Theory of games and economic behavior." *The Bulletin of the American Mathematical Society* 51 (1945):498-504.

- Wang, Y., C. Tu, L. Cheng, C. Li, L.F. Gentry, G.D. Hoyt, X. Zhang, and S. Hu "Long-term impact of farming practices on soil organic carbon and nitrogen pools and microbial biomass and activity." *Soil and Tillage Research* 117 (2011):8-16.
- Weber, E.U., and R.A. Milliman "Perceived risk attitudes: Relating risk perception to risky choice." *Management Science* 43 (1997):123-44.
- West, T.O., and G. Marland "A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: comparing tillage practices in the United States." *Agriculture, Ecosystems & Environment* 91 (2002):217-32.
- West, T.O., and W.M. Post "Soil organic carbon sequestration rates by tillage and crop rotation." *Soil Science Society of America Journal* 66 (2002):1930-46.
- Whitten, S.M., and A. Coggan "Market-based Instruments and Ecosystem Services." *Ecosystem Services in Agricultural and Urban Landscapes* (2013):178-93.
- Wibbenmeyer, M.J., M.S. Hand, D.E. Calkin, T.J. Venn, and M.P. Thompson. "Risk preferences in strategic wildfire decision making: a choice experiment with US wildfire managers." *Risk analysis* 33 (2013): 1021-1037.
- Williams, J.R., S. Mooney, and J.M. Peterson "What is the carbon market: Is there a final answer?" *Journal of Soil and Water Conservation* 64 (2009):27A-35A.
- Williams, J.R., M.J. Pachta, K.L. Roozeboom, R.V. Llewelyn, M.M. Claassen, J.S. Bergtold, M.A. Marchant, and D.J. Bosch "Risk analysis of tillage and crop rotation alternatives with winter wheat." *Journal of Agricultural and Applied Economics* 44 (2012):561.
- Williams, J.R., T.W. Roth, and M.M. Claassen "Profitability of alternative production and tillage strategies for dryland wheat and grain sorghum in the Central Great Plains." *Journal of Soil and Water Conservation* 55 (2000):49-56.
- Wu, J., and B.A. Babcock. "The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications." *American Journal of Agricultural Economics* 80(1998): 494-511.
- Young, L.M. "Carbon sequestration in agriculture: The US policy context." *American Journal of Agricultural Economics* 85 (2003):1164-70.
- Zeuli, K.A., and J.R. Skees "Will Southern Agriculture Play a Role in a Carbon Market?" *Journal of Agricultural and Applied Economics* 32 (2000):235-48.
- Zibilske, L., J. Bradford, and J. Smart "Conservation tillage induced changes in organic carbon, total nitrogen and available phosphorus in a semi-arid alkaline subtropical soil." *Soil and Tillage Research* 66 (2002):153-63.

Zotarelli, L., P. Zatorre, M. Boddey, S. Urquiaga, P. Jantalia, C. Franchin, R. Alves “Influence of no-tillage and frequency of a green manure legume in crop rotations for balancing N outputs and preserving soil organic C stocks.” *Field Crop Research* 132 (2012):185-195.

Appendix A - Stated choice contract instructions

WILLINGNESS TO ADOPT SOIL CONSERVATION PRACTICES

Name: _____

Workshop: _____

We are interested in your willingness to adopt and intensify conservation practices on your **cropland** under different contractual arrangements and different system characteristics. You will be asked to evaluate 12 scenarios. For each scenario you will be asked whether you would be willing to adopt a given bundle of conservation practices or to stay with the status quo. The status quo represents what you are currently doing. Although you may have already adopted all the practices presented to you under a particular scenario, please take into consideration the rest of the contract features before making your decision. You could still choose to adopt the contract if it is favorable.

When considering each scenario, assume a program professional will inventory the land you enroll and will verify that you are complying with the contract. The length of each contract is 5 years. If you fail to comply with the contract you will be required to make a full repayment of the incentive payments you have received plus any administrative costs. For a given contract option, there is not a minimum acreage requirement for enrollment and you choose the number of acres to enroll.

Please evaluate each scenario independently. Other programs may exist that have different contract features, but when evaluating each scenario please consider only the contract features presented to you in this exercise.

Each scenario will present different contractual options with the following features:

Contract Feature		Description
Conservation Practices	Continuous No-Till	Consists in planting crops directly into the crop residue without disturbing the soil with tillage. This practice will be in place year round on the cropland enrolled during the length of the contract.
	Conservation Crop Rotation	Implementation of a three or more year rotation with three or more crops types. The rotation includes a combination of high residue crops, grasses and/or legumes.
	Cover Crops	Planting a single or multiple cover crop species between regular cash crops to protect the soil and improve soil organic matter. The crop residue should not be burned. Some cover crops species that could be grown are: -Legumes: winter peas, hairy vetch, cowpeas, crimson clover, sunn hemp, etc. -Cereal: rye, oats, millet, etc. -Grass: sorghum-sudangrass hybrid, etc. Variable costs of planting and managing (fertilizing, applications and termination) cover crops in Kansas range from \$40/acre to \$100/acre.
	Variable Rate Application of Inputs	This practice requires using site-specific information for input application rates within a field. Methods used can be sensor-based (input application equipment has sensors that calculate application rates in the field) and map-based (consisting of information gathering methods like remote sensing, topographical mapping, soil and/or plant tissue testing, yield monitoring to create site-specific application maps). Variable rate application of fertilizer (deliver and spread) could range from \$8/acre to \$25/acre. Extra charge for variable rate seeding could range from \$2/acre to \$5/acre.

Incentive payment	The incentive payment is offered annually during the length of the contract. The incentive payment is in addition to any difference in net farm income.
Incentive Program	<p>Incentive program refers to the type of mechanism through which the program is offered, administered and regulated. Two programs evaluated here are:</p> <p>a) Federal program: A voluntary conservation program administered by the government via the USDA's Natural Resources Conservation Service (NRCS). This program is comparable to the Conservation Stewardship Program (CSP) or the Environmental Quality Incentives Program (EQIP) where farmers and ranchers are rewarded for taking on conservation activities that improve the long-term sustainability of natural resources on their farms.</p> <p>b) Carbon Credit Payment through a Carbon Market: Climate change policy has long been debated in the U.S. A carbon credit trading mechanism that controls carbon emissions has been one instrument proposed to mitigate climate change.</p> <p>The conservation practices evaluated here have the potential to reduce emissions and/or to enhance the storage of carbon in the soil (this is known as soil carbon sequestration). Carbon sequestration is believed to mitigate the effects of climate change. However, there are additional benefits from sequestering carbon in the soil. These benefits are the improvement of water and nutrient retention, reduction of soil erosion, improvement of soil tilth and productivity, and improvement of wildlife habitat and biodiversity.</p> <p>Carbon stored in the soil (carbon credits) can be aggregated by a third party and traded in a private market where large polluting companies can buy them to offset their emissions. You as a farmer could contract with this third party to receive a payment for the carbon credits earned from the carbon sequestered in your land as a result of using certain conservation practices.</p>
Off-farm Environmental Benefits	<p>Sediments, nitrogen and phosphorus are the number one pollutants of water bodies in Kansas. These pollutants can be transported to downstream water bodies in water runoff and through nutrient leaching. Another important pollutant is carbon dioxide which is believed to contribute to climate change.</p> <p>The conservation practices evaluated here reduce runoff and soil removal, reduce nutrient losses and improve nutrient cycling. They can also result in soil carbon sequestration or reduction of carbon emissions. You will be provided with a measure of the potential impact of the bundle of practices stated under each scenario. This benefit does not refer to the environmental benefits on your farm but rather the benefits to downstream water quality and air quality.</p> <p>Combinations of these practices can result in Low, Moderate or High off-site environmental benefits according to their ability to reduce sediment and nutrients transported to water bodies off the farm, reductions in carbon emission and carbon sequestration potential. The level of benefits provided is affected by your management of these practices as well as other climate variables.</p>

<p>Riskiness: Impact on Net Farm Income</p>	<p>Introducing new practices into your cropping systems may change its dynamics. Some of the practices evaluated in this exercise can increase yields if implemented correctly. However, optimal benefits may not be observed in the first years. Some of these practices can reduce costs by reducing labor requirements, fuel, and pesticides use, but may require some additional investment or more intensive management. This could increase costs. In addition, many other environmental factors like weather or soil characteristics can affect your final costs and crop yields. Proper management is a key factor in ensuring income gains and stability.</p> <p>You will be presented with potential net income changes with their probability of occurrence for each combination of conservation practices. When evaluating changes in net farm income, take into consideration the average net farm income reported earlier in this survey to get an idea of the impact change.</p>
--	---

Appendix B - Mean-standard deviation approach estimated with a random parameters logit

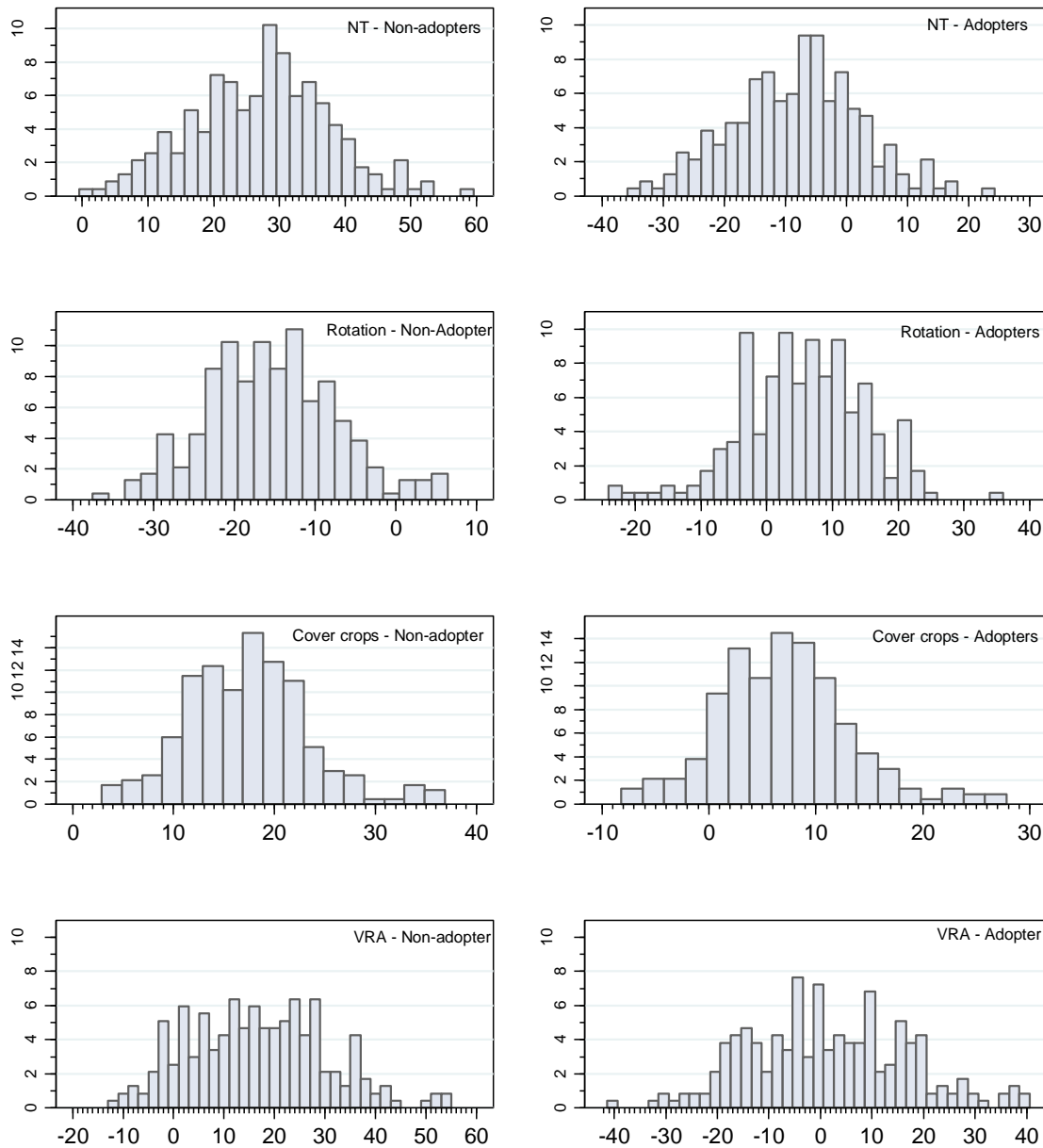
Table B.1 Mean-standard deviation approach – Parameter estimated with a random parameters logit

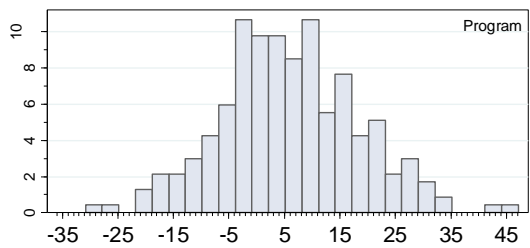
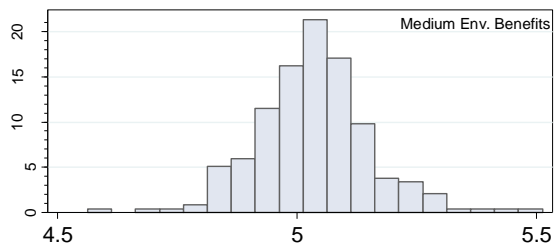
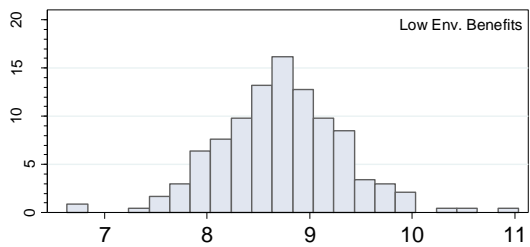
	Parameter estimates	Standard Error
Constant	-12.5537 ***	(1.8503)
<i>Expected net returns</i>	0.1191 ***	(0.0183)
<i>St. Dev. of net returns</i>	-0.0336 **	(0.0144)
<i>Payment</i>	0.0492 ***	(0.0025)
<i>Program</i>	-0.2531 **	(0.1037)
<i>NT</i>	-1.2993 ***	(0.1681)
$NT_j \times NT_{SQ}$	1.7732 ***	(0.1998)
<i>Rot</i>	-0.7019 ***	(0.1602)
$Rot_j \times Rot_{SQ}$	0.4561 **	(0.1906)
<i>Cover</i>	-0.7578 ***	(0.1264)
$Cover_j \times Cover_{SQ}$	0.5206 ***	(0.1951)
<i>VRA</i>	-0.8566 ***	(0.1225)
$VRA \times VRA_{SQ}$	0.8695 ***	(0.2039)
<i>LowEnv</i>	-0.3865 ***	(0.1274)
<i>MidEnv</i>	-0.2545 **	(0.1264)
σ_u^2	2.3615 ***	(0.3568)
No. of Observations	2808	
Log Likelihood	1452.9	
AIC	2937.8	
Pseudo R-squared	0.253	
Adjusted R-squared	0.244	

*, **, *** statistically significant at the 1%, 5% and 10% level. Standard errors in parenthesis.

¹ Carbon Credit Payment through a Carbon Market was used as the base scenario.

Figure B.1 Distribution of farmers' WTA for the mean-standard deviation approach estimated with a random parameters logit





Chapter 4 - Modeling the factors affecting farmers' timing of adoption of in-field conservation cropping practices

4.1 Introduction

Current and future agricultural production needs to tackle problems such as environmental degradation, increasing public awareness of environmental concerns and demand for sustainable production (Sassenrath et al., 2008). Conservation practices play an important role in the sustainability of agricultural production. There is a large variety of conservation practices that address different environmental issues or simply prevent environmental degradation from occurring. Some conservation practices that improve soil conservation, like conservation tillage and crop rotation, have largely been adopted in the US. However the adoption of practices, like variable rate application of inputs, has been slower. This lower adoption rate may be due in part to farmers being unaware of or uneducated about this technology (Daberkow and McBride, 2003). Given the significant conservation efforts by different local and federal government agencies, understanding farmers' motivations and their decision-making processes concerning conservation on-farm is important. Studying farmers' adoption decisions and the process provides government, extension and agribusiness with important insights into the adoption of important conservation technologies and the key aspects that need to be addressed to increase the level of conservation efforts being made by producers.

Numerous modeling approaches have been used to study the adoption of conservation practices and new agricultural technologies (Feder and Umali, 1993; Knowler and Bradshaw, 2007; Prokopy et al., 2008). Many adoption studies rely on approaches to model the adoption at

a given point in time or are cross-sectional in nature and are not able to take account of the timing (speed)⁸ of adoption. These studies often compare the differences in the factors between the group of adopters and those of non-adopters from a static point of view. Thus, these studies do not consider the process of adoption over time and how some factors may not only affect the decision to adopt, but also the timing of adoption. In the same token, some factors do not directly restrict the adoption of conservation practices, but may in fact delay adoption of a practice (Fuglie and Kascak, 2001).

The diffusion of technologies is a gradual process; it takes time for the information about these new practices to be disperse within the farming community (Jabbar et al., 2003; Jaffe et al., 2002). Given that farmers adopt a conservation practice based on their knowledge or expectations about the benefits of the practice, the timing of information collection (learning) and formation of expectations is important (Au and Kauffman, 2003) and may not be captured in traditional binary adoption models, which are often cross-sectional (Burton et al., 2003). Diffusion studies, while accounting for the dynamic nature of the diffusion of agricultural technologies, have done so at the aggregate level and have not been able to capture farm-level characteristics that affect the adoption process at the individual level (Fuglie and Kascak, 2001).

Differences in farmers' and farm management characteristics make farmers likely to adopt at different points in time (Fuglie and Kascak, 2001). The process and timing of the adoption of agricultural technologies is important (Hoppe, 2002). Interaction and learning from other adopters and the process and knowledge accumulation which takes place over time are

⁸ Timing and speed of adoption are used interchangeable in this study and they indicate the time it takes for a farmer to adopt a certain agricultural practices.

important determinants in the diffusion of technologies (Fischer et al., 1996; Jabbar et al., 2003; Llewellyn, 2007). In addition, the adaptability of conservation practices into farmers' production systems is important (Hudson and Hite, 2003), and is likely to change over time as farmers systems are adapted to changing agronomic, climate, ecological, economic, policy, social and technological changes. Knowing the factors that play a role in the timing of adoption is important for agricultural educators (e.g. extension and agribusiness) and policymakers. Knowledge about the factors that accelerate or slow adoption for particular practices can be a useful information tool used to identify target populations where adoption can be potentially slow, allowing for the creation of programs that tackle barriers to adoption faced by farmers.

The study presented here uses duration analysis to examine the timing of adoption of continuous no-till, cover crops and VRA of inputs. While previous studies have examined the adoption of these practices, they have done so from a static point of view. The time it takes for farmers to adopt a practice and the factors that accelerate or slow the adoption process have not been extensively evaluated. This study will examine farmer and farm management characteristics and how these factors affect the timing of adoption of in-field conservation practices in Kansas.

4.1 Objective

The purpose of this study is to examine factors affecting the timing of adoption of continuous no-till, cover crops, and variable rate application of (VRA) of inputs for Kansas farmers to gain insight regarding the time-path diffusion of these conservation cropping practices since their introduction into the agricultural community. These practices provide numerous benefits to the environment, can provide profit advantages, and are commonly known and adopted at different

degrees in the study region. A duration analysis was used to account for the dynamics of adoption and changing factors that affect farmer's likelihood of adoption. Specifically, this study will analyze the effect of profitability factors, farmers' demographics, farm and farm management characteristics, attitudinal factors, and site-specific characteristics on the duration of farmers decision to adopt a particular practice. This duration begins from the date on which a farmer started operating their farm or from the date the practice was available if the practice was introduced after the farmer started their operation and until the date in which the practice was adopted on the farm. In other words, the study is examining what factors impact how long it takes a farmer to adopt these conservation practices. In addition, the study seeks to investigate how conservation on the farm affects the speed (timing) of adoption of other conservation practices. Using duration models allows for the temporal modelling of adoption and the heterogeneity in the timing of the adoption decision (Abdulai and Huffman, 2005).

4.2 Literature review

4.2.1 Conservation practice adoption

There is a large body of literature examining the adoption of conservation practices. Many of these studies have used discrete choice models, such as the binary logit or probit model to analyze factors that differentiate adopters from non-adopters at a particular point in time (commonly at the time a survey was conducted) or across a particular cross-section with no time dimensions examined (Belknap and Saupe, 1988; Davey and Furtan, 2008; Rahm and Huffman, 1984; Soule et al., 2000).

Gould et al. (1989) studied the adoption of conservation tillage as a two-stage process. In the first stage of the process, farmers recognized the existence of a problem with soil health and in the second stage the farmer decides upon the level of conservation to help remedy the problem. Gould et al. (1989) found that the perception of a soil problem was an important factor affecting farmers' decisions. Other factors that have shown to affect the adoption of soil conservation practices, such as conservation tillage, are education, farm size, income, age, debt ratio, percentage of land devoted to row crop production, and weather. Rahm and Huffman (1984) found that the size of the farm operation and soil characteristics affected the adoption of reduced tillage in corn production and that farmers' level of education is an important determinant in the decision process. Soule et al. (2000) studied the factors affecting the adoption of conservation practices and structural practices among corn producing farmers, with different types of contractual arrangements. They found that land tenure was an important factor in the adoption of conservation tillage practices.

A study of conservation tillage adoption in Oklahoma found factors such as age, farm size and crop rotation to be important factors explaining the adoption decision. This study found that farmers with a continuous wheat rotation and livestock production were less likely to adopt these practices (Vitale et al., 2011). Davey and Furtan (2008) studied the adoption of conservation tillage in Canada using a binary probit model and census data over three different years: 1991, 1996 and 2001. They found that farm size, weather and soil characteristics were important determinants of adoption. (D'Emden et al., 2008) studied the adoption of conservation tillage in Australia using a binary logit model. They found that attendance at extension programs and the benefits of conservation tillage to cropping systems in the short term were both important

factors affecting adoption of this practice. Long-term benefits like erosion reduction were not as significant.

Larson et al. (2008) investigated the factors affecting the adoption of remote sensing for variable-rate application of inputs in cotton production in the southern US. They found that younger, educated farmers who operated larger farms were more likely to adopt VRA technologies. Daberkow and McBride (2003) used a two-stage model to evaluate farmers' awareness of precision technologies and the adoption of these practices. They found that farmers' awareness of VRA technologies, computer knowledge, on-farm employment and farm size positively increased the likelihood of adoption.

A study of the adoption of cover crops by Singer et al. (2007) identified the factors affecting the use of cover crops by farmers in the US Corn Belt, including current or past use of cover crops. Their results suggested that crop diversity was the most significant factor affecting the use of cover crops. Perceived yield and soil benefits seem to also increase farmers' likelihood of adopting cover crops. In addition, this study revealed that farmers who used covers crops planted them in only 6% of their crop area (Singer et al., 2007). A study by Bergtold et al. (2012) examined the factors affecting the adoption of cover crops and the perceive yield benefits from adoption by farmers in Alabama. They found that farmers who irrigate their crops and perceived greater environmental benefits from cover crops were more likely to adopt. Their results suggested that the percentage of rented land was a negative factor in farmers' likelihood of adoption. Other studies have examined the adoption of different conservation practices and agricultural technologies. For a review of other studies in the adoption literature, see Feder and Umali (1993), Knowler and Bradshaw (2007), and Prokopy et al. (2008).

4.2.2 Duration analysis and technology adoption

Duration analysis has been commonly used in the medical and engineering fields, and is becoming more common in economic and agricultural studies. Specifically, a number of studies have employed duration analysis to examine the time path of adoption and to account for the dynamic nature of the adoption process of agricultural technologies. In the adoption literature, duration models that account for the temporal aspect of adoption and have been applied to the study of organic farming (Burton et al., 2003); conservation tillage (D'Emden et al., 2006; Fuglie and Kascak, 2001); soil nutrient testing and integrated pest management (Fuglie and Kascak, 2001); weed control practices (Murage et al., 2011); fertilizer and herbicide (Dadi et al., 2004); drip irrigation (Alcon et al., 2011); and other production technologies (Abdulai and Huffman, 2005).

Burton et al. (2003) studied the adoption of organic horticulture in the United Kingdom using duration analysis. They found that the probability of adopting organic farming methods declines after the farmer has been farming for five years. In addition, attitudinal factors were important determinants of the timing of organic adoption, while factors such as education, farm size, household size, and income from farming were not found to be significant factors.

Dadi et al. (2004) studied the adoption of fertilizer and herbicide by farmers in Ethiopia. Their findings suggest that the speed of adoption of fertilizer was more rapid than the speed of adoption of herbicides. Factors that accelerated adoption in their study were the availability of credit, output prices, and closeness to markets. Factors such as farmers' education, awareness of technologies, and farm size were not significant determinants of the speed of adoption. Murage et al. (2011) studied the timing of adoption of weed control technology in corn production in Kenya using a duration model. They found that education, farm size and household size

increased the speed of adoption of this technology. Their results also suggested that field days were a more effective method at accelerating the adoption decision.

Alcon et al. (2011) investigated the adoption of drip irrigation in Spain from 1975 to 2005. They found that factors such as credit availability, water availability, price of water, information sources and trialing of prior technologies were significant determinants of the rate of adoption. The adoption of water conservation practices in Kenya and the Philippines was also analyzed by (Oostendorp and Zaal, 2012) using duration analysis. They found that land ownership was an important factor affecting adoption. Their findings also suggested that the likelihood of adoption decreased over time.

Abdulai and Huffman (2005) examined the timing of adoption of crossbred-cow technology in Tanzania. They found that reductions in the price of the technology, farmers' education, access to credit, and the number of farmers who have adopted the practice in the same village reduced the timing of adoption. In contrast, distance to the local market slowed the rate of adoption. They also found positive duration dependence, indicating that farmers were more likely to adopt the technology with time.

Fuglie and Kascak (2001) used duration analysis to examine the dynamics of the adoption of conservation tillage, soil nutrient testing, and integrated pest management using data from a USDA survey conducted from 1991 to 1993, covering different watersheds in the High Plains, Iowa-Illinois, Central Nebraska basins, Mississippi Embayment, Upper Snake River Basin, Susquehanna River Basin, and White River Basin. In their study, they investigated the effect of farmer and farm characteristics, as well as natural resource characteristics (e.g. soil quality and rainfall) on adoption. They found a faster rate of adoption for conservation tillage during the late 1980s. Education, farm size, source of farm income, and soil characteristics were

important factors in explaining the timing of adoption in their study. They also found that farmers with better soil quality adopted more rapidly than farmers with poor soil quality. Duration analysis was also applied by (D'Emden et al., 2006) to study the adoption of conservation tillage by grain producers in Australia from 1983 to 2003. They found that the decrease in the price of glyphosate was an important factor accelerating adoption and that lower precipitation levels increased farmers' likelihood of adoption.

4.3 Methods and data

4.3.1 Conceptual framework

The adoption of conservation practices is a dynamic process. Farmers evaluate a practice and decide to adopt at a precise point in time when introducing the practice into their production systems maximizes their utility (Pannell et al., 2011). Different components may be evaluated as part of the utility farmers derive from adopting a particular technology, including economic, social and/or environmental benefits (Pannell et al., 2006; Pannell et al., 2011). For example, if farmers are profit maximizers, they would adopt a technology if they find it profitable (Hoppe, 2002). More than likely, farmers have multiple goals or objectives (Pannell et al., 2006). Farmers may also seek to maximize their utility through environmental stewardship, by improving soil health. In this case, in addition to profit, the farmer would want to adopt a technology if doing so achieves their environmental objectives, as well. If a practice does not maximize farmers' utility at a particular point in time, then farmers delay adoption until new information or knowledge about the suitability of the practice for meeting their economic, social and environmental goals

becomes available (e.g. cost of the technology, profitability, soil or environmental benefits, etc.) (Hoppe, 2002).

An important temporal aspect in the adoption process in assessing a technology's suitability is the adaptability of the practice. At the beginning, the uncertainty from adopting a new practice is high, however, with time the uncertainty is reduced (Pannell et al., 2006). In some cases, farmers may find it optimal to delay adoption until the practice becomes viable for their cropping system. That is, the new technology or practice can most easily be assimilated into their current cropping system with the lowest transaction cost, while meeting their objectives for adopting the practice (Ghadim and Pannell, 1999; Pannell et al., 2006). In some cases, this point is reached when sufficient information has been gathered to make an optimal decision (Fischer et al., 1996; Jabbar et al., 2003). Some factors that may affect the adaptability of a practice or technology and knowledge acquisition could be farm size, physical capital requirements, human capital requirements, weather, geography, and complementarity with other agricultural practices already used in the farmer's cropping system (Ghadim and Pannell, 1999; Jabbar et al., 2003).

The compatibility of a conservation practice, which concerns the stage of development of the technology, is another factor that will affect the adoption of a new technology or practice. For example in the case of VRA adoption, constraints to adoption have been linked to equipment and software issues (Robertson et al., 2012). External factors such as the complexity of the practice, the extent of trial ability, social network interactions, and farmer's characteristics will impact farmers' perceptions of the adaptability and compatibility of a new practice, affecting the evaluation of that practice in the adoption process and in turn the decision of when to adopt (Pannell et al., 2011). For example, risk averse farmers may delay adoption to avoid uncertainty

and minimize the cost of information, which may become available as more farmers adopt a practice (Sassenrath et al., 2008).

The conceptual framework examines the timing of adoption of conservation practices by farmers, building on the framework used by Abdulai and Huffman (2005). Consider a farmer, indexed by i , who is considering the adoption of a conservation practice. Let $\pi_{it}^E(x_{it})$ represent the expected profitability of the adoption of the conservation practice at time period t as a function of a set of explanatory factors that can vary across individuals and time (x_{it}). While profit is a strong motivation to adopt a practice, as mentioned earlier, it may not be the only objective. That is, farmers may be environmental stewards or want to provide security for the farm for future generations. Thus, a utility framework is utilized to capture these multiple objectives by the farmer. Let farmer i 's expected utility from farming in time period t be represented by $U_{it}^E = U_i^E[I_{it}, \pi_{it}^E(x_{it}), z_{it}, w_{it}, r_i, \Gamma_{it}]$. It is assumed that farmers' expected utility is increasing in π_{it}^E such that $\partial U_{it}^E / \partial \pi_{it}^E \geq 0$. I_{it} is an indicator function taking a value of 1 if the farmer adopts the conservation practice in time period t and zero otherwise. The other arguments of farmer i 's expected utility are farmer demographics (z_{it}); farm and farm management characteristics (w_{it}); attitudinal factors (r_i); and site-specific characteristics Γ_{it} . These different factors play an important role in farmers' motivation to adopt a conservation practice as shown in prior research (Robison et al., 1984; Skaggs et al., 1994).

The goal of the farmer is to maximize expected utility over time, i.e. $\max_t \sum U_{it}^E(\cdot)$.

Letting t^* represent the optimal time to adopt the conservation practice, the utility maximization

problem implies the following condition:
$$\sum_{t=1}^{t^*-1} U_{it}^E(I_{it}=0, \dots) + \sum_{t=t^*}^T U_{it}^E(I_{it}=1, \dots) \geq \sum_{t=1}^T U_{it}^E(I_{it}=0, \dots),$$

where I_{it} is an indicator variable taking a value of 1 to indicate adoption beginning in time period t^* and zero otherwise. The utility is maximized over the indicator variable and adoption occurs when the above condition is met. That is, a farmer will adopt in time period t^* if the stream of utilities over time after adopting a conservation practice at time t^* is greater than or equal to the sum of utilities when the practice is not adopted (or adopted at a different time). This suggests that a conservation practice is adopted not only when its expected benefit is positive, but by choosing t^* , we ensure that the adoption occurs at the point in time when that benefit is maximized (Abdulai and Huffman, 2005). Operationalizing this model requires that what is observed for the farmer is the actual point of adoption or t^* . Thus, we can look at the timing of adoption from a probabilistic framework empirically.

4.3.2 Empirical model

Duration analysis will be employed to study the length of time it takes a farmer to adopt a conservation practice (i.e. transition states). Let the time of adoption be represented by a random variable T . Then the probability distribution of the length of time (i.e. the duration) to adoption can be represented by the distribution function $F(t) = \text{Prob}(T < t)$. That is, the probability of adopting a conservation practice before time period t is given by $F(t)$, where t is a particular realization of T . Associated with this distribution, is its corresponding density function $f(t) = dF(t)/dt$, which provides the relative frequency of adopting at time period t (Greene, 2012; Kiefer, 1988).

The probability that a farmer adopts after time t can be represented by the well-known survival function (Lancaster, 1992):

$$(4.1) \quad S(t) = 1 - F(t) = \text{Prob}(T \geq t)$$

Using $F(t)$ and $S(t)$, the probability that a farmer would adopt in a given interval of time Δt can be modeled using the hazard rate (or function):

$$(4.2) \quad \lambda(t) = \lim_{\Delta t \rightarrow 0} \frac{\text{Prob}(t \leq T \leq t + \Delta t \mid T \geq t)}{\Delta t} = \frac{f(t)}{S(t)} = \frac{-d \ln S(t)}{dt}$$

The hazard rate represents the rate at which a farmer would adopt after he has farmed for t years, or alternatively, after the practice has been available for t years, whichever is latest. Different parametric specifications for the hazard function have been proposed, namely, exponential, Weibull, log-logistic, lognormal, and inverse normal (Kalbfleisch and Prentice, 2011; Lancaster, 1992).

A graphical nonparametric assessment of the proper functional form to utilize to model $F(t)$ can be done using the Kaplan-Meier estimator, which can be used to graphically assess the shape of the distribution to determine the distributional form of the survival and hazard functions (Kalbfleisch and Prentice, 2011; Lancaster, 1992). Based on the analysis of the Kaplan-Meier estimator of the survival curve (discussed later in the results section), the Weibull model, which is widely used to model monotonically increasing or decreasing hazard functions, was chosen to model the duration of adoption in this study (Greene, 2012).

The hazard, survival and density functions, assuming a Weibull distribution for $F(t)$, are given by (Greene, 2012):

$$(4.3) \quad \lambda(t) = \lambda p(\lambda t)^{p-1}$$

$$(4.4) \quad S(t) = \exp[-(\lambda t)^p]$$

$$(4.5) \quad f(t) = \lambda p(\lambda t)^{p-1} \exp[-(\lambda t)^p]$$

where λ and p are distributional parameters. Equation (4.3) is the hazard function, Equation (4.4) represents the survival function, and Equation (4.5) represents the density function for the timing of adoption. When $p = 0$, the distribution reduces to the exponential case, where the probability of adopting is the same in any year after the farmer begins farming.

4.3.3 Survey method

A survey was administered during a series of workshops held across 10 locations spanning the state of Kansas from December 2013 to March 2014. Workshop locations were selected based on different weather, landscape and farm demographic characteristics. The cities where the workshops were held were: Salina, Great Bend, Colby, Dodge City, Wellington, Pratt, Hiawatha, Topeka, Manhattan, and Parsons, Kansas. Prior to administering the survey, the instrument was field tested with farmers during two focus groups held in Salina and Wellington, Kansas.

The sample of farmers contacted for the survey was obtained from the Kansas Farm Management Association (KFMA), which services over 2,300 farms that grow crops and livestock across the state of Kansas. Of these farms, approximately 76% are identified as primarily crop producers and 16% are identified as crop/livestock producers. A total of 1,513 farmers from the KFMA were mailed letters to attend face-to-face workshops. Of the farmers

contacted, 40 were no longer farming, were deceased or could not be located and 432 responded to the letter. Some of the farmers who responded were interested in participating, but were not able to attend the workshops on the dates they were held. Of the farmers who responded to the letter, 250 farmers were able to attend the workshops, yielding a response rate of 30% and an attendance rate of 17%. Workshop attendees were compensated for their time and travel expenses with a stipend of \$125 in cash. It is important to note that farmers who had conservation practices in place may have been more likely to attend the workshops; however, given the nature of slightly more intensity of the practices under study, they were the target population.

Participating farmers were asked to complete a survey with questions covering their farming history, farm operation, and conservation on their farm. The survey required respondents to provide information on the practices adopted and the date in which these practices were adopted. Farmers also provided information on the date in which they started operating any part of their farm. Specifically, Question 22 in the survey was used to estimate the time of adoption for the different conservation practices. Explanatory factors and summary statistics are provided in subsection 4.4.4.2.

4.3.4 Survey data

Table 4.1 presents a comparison of respondents' demographics with those of Kansas farmers using the 2012 U.S. Census of Agriculture (NASS-USDA, 2014) and the demographics of KFMA members in 2013 (KFMA, 2014). The average sample age was 56 years and was comparable to the average Kansas farmer (58 years) (U.S. Census of Agriculture). The average farm size (including CRP land) of the respondents (2,508 acres and sales value of \$400,000 to

\$599,999) was larger than the average farm size reported in the 2012 Census of Agriculture (747 acres and sales value of \$298,845). This particular study focuses on medium to large farms, excluding small hobby farmers, retired farmers, and very large operations which represented a significant share of the total farms in Kansas (Lambert et al., 2007; NASS-USDA, 2014).

Table 4.1 Average farm characteristics

Variable	N	Mean	SD	Min.	Max.	Mean 2012 Census of Agriculture	Mean 2013 KFMA
Age (yrs.)	234	56	13	20	84	58	----
Acres	234	2,508	1,981	110	14,875	747	2,196
Sales	234	6.20 ^b	2.04	1	9	\$ 298,845	\$618,416

^a Source: National Agricultural Statistics Service, USDA (2014)

^b Mean sales of 6.20 corresponds to the sales category of \$400,000 to \$599,999

4.3.5 Model estimation

This study examined the timing of adoption of continuous no-till, cover crops and VRA of inputs. For the purpose of this research, the conservation practices examined are defined as follows:

- Continuous no-till: Consists in planting crops directly into the crop residue without disturbing the soil with tillage, for all the crops in a rotation within a particular field.
- Cover crops: Planting a single or multiple cover crop species between regular cash crops to protect the soil and improve soil organic matter.
- VRA of inputs: This practice consists in using site-specific information for input application rates within a field. Methods used could be sensor-based and/or map-based.

These practices were selected because they are cropping practices commonly known and adopted at different degrees in the region of study. An individual model was estimated for each practice to examine the time relative to the beginning of farming or introduction of the practice, when adoption of the conservation practice occurred. Given that farmers did not provide information regarding the date of adoption for some practices, the number of observations for each practice modeled varied. The start of the time period to adoption ($T = 0$) begun at different years for each farmer. Following (Alcon et al., 2011; Burton et al., 2003; D'Emden et al., 2006), the beginning of the duration for each farmer was estimated as either the year in which the farmer started operating the farm, or alternatively, the year at which the practice was commercially introduced if the farmer started operating the farm prior to the introduction of the practice. For adopters, the dependent variable was then calculated by subtracting the year in which farmers started operating the farm from the year in which the practices was adopted. If the conservation practice was not available until after the initial year of farming, then the timing

of adoption was calculated using the year in which the practice was available to the farmer.

For no-till practices, the year used as the initial year of farmers' exposure to the practice was 1962. While no-till practices were used since the existence of ancient cultures (Triplett and Dick, 2008), those used by mechanized farmers have only occurred in the last century. No-till experiments were conducted as early as 1951 in the U.S., however the practice was not adopted and field trials conducted until 1961 (Derpsch et al., 2010; Doraszelski, 2004). Successful introduction of no-till practices in mechanized farms was reported in 1962 (Derpsch, 2004). Specifically, the development of this practice in corn started in 1960 (Triplett and Dick, 2008). For VRA, 1993 was used as the date in which farmers had initial access to precision technologies. By 1993, the introduction of GPS made it possible for the development of crop monitoring and yield mapping (Taylor and Whelan, 2005), technologies that have been commercially available since the early 1990s (Daberkow and McBride, 2003). For cover crops, there was not an identifiable date when the practice was introduced since different types of cover crops have been used for a long time.

In some cases, conservation practices were adopted on a farm by previous operators. This represents a case of left truncation if information on the adopter and the path of adoption are unknown. In this study, observations with left truncation were omitted following (Alcon et al., 2011). The exit or date of adoption was estimated as the year when adoption took place for adopters ($T=t$). For right censored observations, where adoption had not taken place by the date of the survey (c), the survey date was taken as the exit time, i.e. $T = \min(t, c)$ (Kiefer, 1988). For censored observations, the process is still ongoing and adoption could take place sometime after t , but it is not observed.

4.3.5.1 Maximum likelihood estimation

The parameters of the duration model can be estimated using Maximum Likelihood estimation. Given that the time of adoption for farmers who had not adopted a practice by the time of the survey is unknown, the data is censored and estimation needs to account for the censored nature of the data (Greene, 2012). Censoring is accounted for in the Likelihood function, where the likelihood function for a farmer who has adopted a practice is the density of time it took for the farmer to adopt, $L = f(t) = S(t)\lambda(t)$. On the other hand, the contribution to the likelihood function for a farmer who has not adopted a practice is its survival function, $L = S(t)$. The log likelihood function accounting for censoring can then be written as (Greene, 2012):

$$(4.6) \quad \ln L(\theta) = \sum_{i=1}^n \delta_i \ln f(t_i | \theta) + (1 - \delta_i) \ln S(c | \theta)$$

or

$$(4.7) \quad \ln L(\theta) = \sum_{i=1}^n \delta_i \ln \lambda(t_i | \theta) + \ln S(c | \theta)$$

where i represents the index of farmer observations, $\theta = (\lambda, p)$ is a vector of parameters, c indicates the censoring time (time of the survey), and δ_i is an adoption indicator (taking a value of 1 if farmer i adopted and zero otherwise). When a farmer has not adopted a practice ($\delta_i = 0$), this indicates that the observation is right censored, adoption has not been observed but it could occur in the future.

The hazard rate can also be allowed to be a function of a vector of explanatory variables x such that:

$$(4.8) \quad \lambda_i(t; x) = \lambda \phi(x, \beta)$$

where λ is a constant or baseline hazard. A commonly adopted functional form for $\phi(\cdot)$ is $\phi(\cdot) = \exp(-x' \beta)$, making Equation (4.8):

$$(4.9) \quad \lambda_i(t; x) = p(\lambda t)^{p-1} \exp(x' \beta)$$

Equation (4.9) indicates that the explanatory variables enter the adoption rate (log failure rate) in a linear fashion. The explanatory variables do not affect duration dependence, (which is given by the parameter p), the explanatory variables affect the Weibull hazard multiplicatively (duration dependence is not a function of the exogenous variables) (Kalbfleisch and Prentice, 2011). It follows then, that the hazard, survival and density of T (Equation 4.3 – 4.5) can be written as:

$$(4.10) \quad \lambda(t) = p(\lambda t)^{p-1} \exp(x' \beta)$$

$$(4.11) \quad S(t) = \exp[-(\lambda t)^p \exp(x' \beta)]$$

$$(4.12) \quad f(t; x) = \lambda p(\lambda t)^{p-1} \exp(x' \beta) \exp[-(\lambda t)^p \exp(x' \beta)]$$

Using the density of time in Equation (4.12) in the Log Likelihood expression in Equation (4.7), this later form reduces to (Greene, 2012):

$$(4.13) \quad \ln L(\beta, \sigma) = \sum_{i=1}^n \left[\delta_i \left(\frac{\ln t_i - x_i' \beta}{\sigma} - \ln \sigma \right) - \exp \left(\frac{\ln t_i - x_i' \beta}{\sigma} \right) \right]$$

where $\sigma = 1/p$. Models like that in Equation (4.9), where the hazard (λ) is a function of exogenous variables are often called accelerated failure time models (Greene, 2012). For more details on how the estimation model is derived, see Greene (2012).

4.3.5.2 Explanatory variables used in the analysis

There are multiple factors that affect farmers' adoption of agricultural technologies. These factors differ by the type of technology adopted and the region where adoption takes place. Some of the determinants of adoption for conservation practices identified in the literature are farm and farm management characteristics; biophysical factors or site-specific characteristics; economic factors; attitudinal factors; and market factors such as input and output prices (Knowler and Bradshaw, 2007). For a comprehensive review of the factors affecting the adoption of different conservation practices in the literature see Baumgart-Getz et al. (2012) and Prokopy et al. (2008). In many cases, the factors evaluated in empirical applications are restricted to the availability of data. In this study, the factors evaluated are: profitability factors (perception of increased income), farmer demographics (age and education), farm and farm management characteristics (farm acres, farm income, crop income, previous practices adopted on the farm), attitudinal factors (risk aversion, stewardship, and if the farmer is a first-time technology adopter), and site-specific characteristics (regional variables). Descriptive statistics of the data are reported in Table 4.2.

In this study, conservation practice profitability is a discrete variable that takes a value of 1 if the farmer indicated that they would only adopt the conservation practices (evaluated in this study) if they perceived it would increase profit, and zero otherwise. This variable was used to control for the profitability of the practice at the time of adoption. If farmers indicated that they

would adopt these practices only if these resulted in higher profits, then it follows that they adopted a practice at a particular point in time because expected profits were higher with the practice than without it. Conversely, if farmers have yet to adopt these practices, then it indicates that they do not perceive these practices as necessarily being economically profitable for them at this point in time (i.e. the production, opportunity or transaction costs could be too high).

Age of the farm operator is expected to be negatively correlated with the speed of adoption of a conservation practice. Older farmers have a shorter planning horizon and are thought to be more averse to change. While some studies have found that younger farmers are more likely to adopt conservation tillage (Davey and Furtan, 2008; Soule et al., 2000) and VRA of inputs (Hudson and Hite, 2003; Larson et al., 2008), other studies have found no statistical relation between the age of the farmer and their willingness to adopt agricultural practices (Abdulai and Huffman, 2005; Finger and El Benni, 2013). In a duration analysis, age was found to slow the time of adoption of drip irrigation (Alcon et al., 2011).

Table 4.2 Descriptive statistics of Dependent and Explanatory Variables

Variable	Mean (Standard Error)			Definition
	Continuous no-till	Cover Crops	VRA	
<i>Dependent Variable</i>				
Duration	25.753 (14.315)	32.043 (14.727)	17.810 (5.723)	Time measured in years that it took for farmers to adopt.
<i>Explanatory Variables</i>				
Profitability	2.252 (0.970)	2.236 (0.974)	2.227 (0.976)	The farmer would adopt the practice only if it increases net returns (1 = yes, 0 = no) .
Age	49.188 (14.247)	55.112 (13.680)	55.310 (13.896)	Farmer's age in years.
College	0.507 (0.501)	0.502 (0.501)	0.513 (0.501)	Farm operator has a college degree (1 = yes, 0 = no) .
Acres	2458.34 (2049.30)	2469.60 (2021.54)	2493.12 (2012.58)	Total crops acres (including crops, grazing, CRP).
FarmInc	74.253 (29.946)	73.610 (30.128)	73.872 (30.305)	Percentage of household income derived from the farming operation.
Crops	73.344 (27.308)	72.437 (27.764)	74.187 (26.970)	Percentage of farm income from crop production.
CNT	-----	0.548 (0.499)	0.576 (0.495)	Farmers was using continuous no-till before adopting this practice (1 = yes, 0 = no) .
CCRot	0.431 (0.496)	0.541 (0.499)	0.578 (0.495)	Farmers was using crop rotation before adopting this practice (1 = yes, 0 = no) .
CCrop	0.072 (0.259)	-----	0.250 (0.434)	Farmers was using cover crops before adopting this practice (1 = yes, 0 = no) .
VRA	0.076 (0.266)	0.393 (0.000)	-----	Farmers was using VRA of inputs before adopting this practice (1 = yes, 0 = no) .
Risk	0.749 (0.435)	0.747 (0.436)	0.728 (0.446)	Risk taking behavior in farm management decisions (1 = risk averse, 0 = otherwise)
Stewardship	0.489 (0.501)	0.481 (0.501)	0.487 (0.501)	Maximizing farm profit is more important than environmental stewardship to the farm's operator(1 = no, 0 = yes) .
Innovators	0.507 (0.501)	0.494 (0.501)	0.504 (0.501)	Farm operator usually adopts new technology (e.g. no-till, new seeds, etc.) before neighbors (1 = yes, 0 = no)
Western	0.215 (0.412)	0.215 (0.411)	0.220 (0.415)	If the farm is located in Western Kansas (1 = yes, 0 = no)
Central	0.413 (0.493)	0.412 (0.493)	0.409 (0.493)	If the farm is located in Central Kansas (1 = yes, 0 = no)
No. Obs.	223	233	232	

VRA = Variable rate application of inputs

Education was included to evaluate the effect of human capital in the timing of adoption. Farmers with a higher level of education are thought to have better access to information and to be able to make more efficient and informed decisions (Rahm and Huffman, 1984). Education has been found to be a significant factor in the adoption of no-till and other conservation tillage practices (D’Emden et al., 2008; Gould et al., 1989; Rahm and Huffman, 1984; Soule et al., 2000). Other studies found no statistically significant effect (Davey and Furtan, 2008). The effect of education is expected to be larger for more complex technologies like in the case of cover crops and VRA application of inputs. Highly educated farmers have been found to be more likely to adopt various VRA technologies (Adrian et al., 2005; Larson et al., 2008; Robertson et al., 2012). In duration analysis applications, education has been found to speed the adoption of agricultural technologies (Murage et al., 2011). A study conducted by (Fuglie and Kascak, 2001) found that farmers with a high school or college degree adopt conservation practices two years earlier than farmers without a high school diploma. Another study found that farmers’ education speeds the adoption of drip irrigation (Alcon et al., 2011). A priori, education is expected to accelerate the adoption process of the three conservation practices evaluated in this study.

Total acres was included in the models to evaluate the effect of operation size on the speed of adoption of a conservation practice. Given that some of these practices may require human/capital investment and may have transaction costs, farmers that operate at a larger scale may be able to distribute the costs of adoption among more acres or enterprises, reducing the unit cost by taking advantage of economies of scale. Therefore, total acres is expected to be a positive factor in the timing of adoption. Previous studies have found a positive relation between size measured in acres and conservation tillage adoption (Davey and Furtan, 2008; Soule et al., 2000). In practices where the investment is greater, as in VRA of inputs, the presence of

economies of scale could be larger. Evidence in the literature suggests that VRA of inputs is more likely to be adopted on larger farms (Adrian et al., 2005; Daberkow and McBride, 2003; Hudson and Hite, 2003; Larson et al., 2008; Robertson et al., 2012). For mid-term or structural practices where there is no gain in economies of scale (e.g. investment is done at the acre level), a negative relation has been found between farm size and adoption (Soule et al., 2000). In duration analysis applied to the adoption of agricultural technologies, the effect of farm size has been mixed. Farm size was found to accelerate the adoption of a weed control technology in western Kenya (Murage et al., 2011). Fuglie and Kascak (2001) found longer lags of conservation tillage adoption as farm size decreased. They estimated an adoption lag of 7 years between the largest and smallest farm in their sample. Conversely, farm size was not found to have a significant effect in duration applications for the adoption of no-till (D'Emden et al., 2006) and drip irrigation systems (Alcon et al., 2011).

The percentage of off farm income is used as a proxy for the time devoted to work on the farm. A higher percentage of off-farm work is expected to slow the adoption of conservation practices. The adoption of agricultural practices require time and investment in learning the new technology (Llewellyn, 2007), which could represent a constraint to adoption for farmers whose main activity is not farming. For technologies like VRA, where a greater investment is required, particular investment in the development of technical skills and time devoted to operating the farm is particularly important. Farmers devoted to full-time farming were more likely to adopt VRA of input technologies (Daberkow and McBride, 2003) and were more likely to adopt conservation tillage (Soule et al., 2000). No significant effect was found in the adoption of other agricultural practices like extensive wheat production systems (Finger and El Benni, 2013).

Another variable included in the analysis was the percentage of farm income from crop production. This variable is expected to have different effects on each practice. Farmers with more livestock are expected to be more likely to adopt cover crops because these can be used for a dual purpose, such as feeding livestock. On the other hand, farmers whose income primarily comes from livestock and who allow their livestock to graze crop residues may be less likely to adopt conservation tillage (Vitale et al., 2011).

Conservation practices used on the farm at the time of adoption was also included to examine that effect of complementarity or substitutionability of conservation practices. A dummy variable was included to indicate if the farmer was using continuous no-till, conservation crop rotations, cover crops or VRA of inputs prior to adopting the practice being examined. Adopting different conservation practices on the farm could also indicate an attitude towards conservation and it is expected to speed the timing of adoption. However, a study by Bergtold and Molnar (2010) did not find evidence that the adoption of one practice influenced the adoption of other practices.

Risk affects the adoption of agricultural technologies in different ways (Marra et al., 2003) and has been found to reduce the adoption of agricultural technologies (Ghadim et al., 2005). Risk affects farmers' willingness to try new practices and the process of knowledge accumulation (Greiner et al., 2009b). Risk averse farmers are thought to adopt practices more slowly than risk-neutral or risk-loving farmers to avoid the cost of uncertainty and the cost of learning the new technology (Sassenrath et al., 2008). For example, (Krause and Black, 1995) suggested that risk averse farmers adopt conservation tillage slower because of the learning costs. In the case of no-till, at initial stages of the diffusion of the technology, studies found the practice to be riskier, and risk aversion was found to be negatively associated with adoption

(Bultena and Hoiberg, 1983). However as no-till technologies improved and improved herbicides were introduced, the risk associated with the practice decreased (Bosch and Pease, 2000). In addition, the way a conservation practices impacts soil quality, production costs, and crop yield variability may affect the way in which risk affects adoption (Kalaitzandonakes and Monson, 1994). Generally, farmers with higher risk tolerance adopt more practices on their farms (Lynne et al., 1988) and are expected to adopt practices more rapidly than risk averse farmers (Chatterjee and Eliashberg, 1990).

Attitudinal factors such as farmers' attitudes toward environmental stewardship are expected to speed the adoption of the conservation practices evaluated in this study. Farmers with conservation motivations were found to be more likely to adopt best management practices in previous empirical studies (Greiner et al., 2009b). In addition, innovators (farmers who considered themselves first time adopters), are expected to adopt more rapidly. However, as discussed by (Pannell et al., 2011), innovators are not always the first to adopt conservation practices. In some cases they may become later adopters if the practice is not attractive or suitable to their production system.

Regional indicators were included to account for differences in the adoption across regions. Due to heterogeneity in land quality and weather, weed pressure and other factors that are not accounted for in the set of explanatory variables, it is important to capture the effect of geographical differences impacting the adoption of agricultural technologies (Green et al., 1996). D'Emden et al. (2008) found differences in the speed of adoption of conservation tillage across regions in Australia. Fuglie and Kascak (2001) found larger lag differences in the adoption of conservation practices across regions in the U.S. Regional factors have also been found to be

significant explanatory variables in the adoption of VRA of inputs (Daberkow and McBride, 2003).

Given the way the variables enter the model and method of data collection, it is implicitly assumed that the explanatory variables do not vary over time, which can be a strong assumption for many covariates. Education may not change much over time as it may be likely that the level of education attained at the time farmers started operating their farm may not have changed afterwards. While attitudinal factors and risk aversion may be affected by knowledge and experience, they could also be related to farmers' personality and it could be argued that, in general, they are relatively constant over time. However, farm size and sales may have been affected by the adoption of the practices and other exogenous factors, and may not be constant.

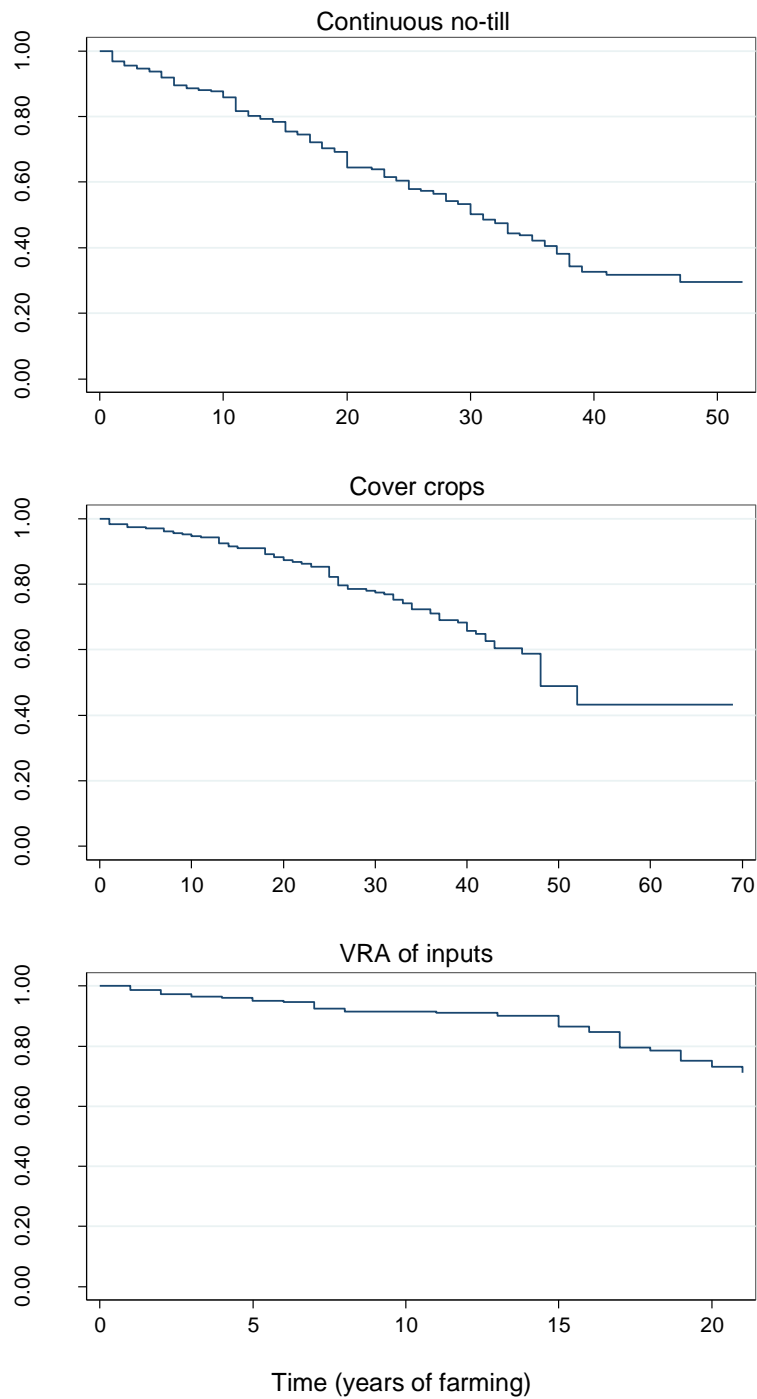
4.4 Results and Discussions

Kaplan Meier survival estimates for the three practices are illustrated in Figure 4.1. The survival function represents the likelihood that a farmer continues farming without adopting the conservation practice. It can be noted that the survival curve for the three practices decreases over time, indicating that the likelihood that a farmer would adopt any of these practices increases over time. The three survival estimates decrease over time, indicating positive duration dependence (i.e. $d\lambda(t)/dt > 0$ in Equation 3). That is, the likelihood of adoption increases with the number of years of farming (Greene, 2012). It can be noted that the adoption of these practices is more rapid during the first years of farming (or introduction of the practice) and later years are characterized by a slower pace of adoption. It can also be noted from the graphs that the adoption of VRA has been slow. Under some conditions, farmers may have an incentive to

delay adoption until a technology is improved or more information becomes available (Chatterjee and Eliashberg, 1990), which could be the case for VRA of inputs.

Since the survival function for the exponential distribution is constant, and first increasing and then decreasing for the lognormal and logistic distributions, the Weibull distribution, characterized for being monotonically increasing (or decreasing), was a good fit for the data in this study (Greene, 2012). The Weibull distribution is appropriate as the probability of adoption is not expected to be constant over time, but to gradually increase. The parametric models were estimated using maximum likelihood estimation in LIMDEP 10. The model estimated was an accelerated failure time model. The “accelerated” refers to the fact that the hazard function is a function of exogenous variables and “failure time” refers to the time measured being the time until adoption occurs (i.e. in some applications this is referred to as failure time). The results of the models estimated are reported in Table 4.3.

Figure 4.1 Kaplan Meier survival estimates



The parameter p , is greater than one for all the conservation practices, indicating positive duration dependence. That is, the likelihood that a farmer would adopt any of these practices increases with the number of years of farming. Over time the cost of technology tends to decrease (Jaffe et al., 2002). In addition, over time, farmers acquire more farming experience and accumulate knowledge and capital. These factors are more likely to increase the likelihood a farmer adopts a conservation practice as more time passes. Given that the adoption of conservation practices by farmers creates an important source of information to assist with the diffusion of the technology to other farmers, the longer a farmer operates a farm, the more they are in contact with an increasing number of adopters over time, reducing uncertainty about the benefits and costs of using a particular practice. There are other external factors that overtime ease the adoption of some practices. For example, the development and improvement of technologies and equipment that facilitate the implementation of a practice. In the case of no-till, it has been suggested that the introduction of herbicides made it possible to speed adoption rates (Doraszelski, 2004).

The parameter estimates for each model represent the effect of an explanatory variable on the conditional probability of adoption at time period t . While the magnitude of the coefficients cannot be readily interpreted, the sign of the parameters can be interpreted as speeding or slowing adoption. A negative coefficient indicates that the effect of a particular variable is to accelerate adoption. On the other hand, a positive coefficient would indicate a factor that would delay adoption. A highly significant factor in the adoption of all conservation practice models was a farmer's age. Younger farmers were found to adopt the three practices faster than older farmers. A potential implication of this result is that, as farmers start operating their farms at a

younger age, efforts should be directed towards those farmers to adopt environmentally sound conservation practices, because as they grow older, they are less likely to adopt.

Farmers who adopt practices only when there is a corresponding increase in profit were found to lag behind those farmers for whom profitability of the practice is not the main driver for adoption. This result was found statistically significant for both continuous no-till and cover crops. This result may indicate that some farmers do not always perceive these practices as being profitable. In addition, farmers for whom profit maximization was more important than stewardship were found to adopt VRA of inputs at a higher speed. This result could indicate that adoption of VRA of input is driven by profit motives and not environmental motives.

A surprising result was that farmers who adopted conservation crop rotation or VRA of inputs adopted continuous no-till at a slower pace than farmers who had not adopted these two practices. Similarly, the adoption of cover crops was found to slow the adoption of VRA of inputs. It has been previously suggested that while farmers may consider the adoption of various conservation practices, when it comes time to adopt additional practices, the higher cost of conservation intensification may make farmers less likely to adopt more practices (Ma et al., 2012). In addition, Cattaneo (2003) found that conservation contracts with a larger bundle of conservation practices in the EQIP program were more likely to be withdrawn. It is possible that farmers see some of these practices as substitutes. They may obtain some benefits from a particular practice, and as a result, the likelihood of adopting an additional practice that provides the same or similar benefits may decrease.

Table 4.3 Accelerated Failure Time estimates

	<u>Continuous no-till</u>		<u>Cover Crops</u>		<u>VRA of inputs</u>	
	Coefficient	SD	Coefficient	SD	Coefficient	SD
Intercept	0.564 **	(0.221)	1.265 ***	(0.257)	2.219 ***	(0.483)
Age	0.058 ***	(0.004)	0.047 ***	(0.004)	0.038 ***	(0.005)
College	-0.118	(0.082)	-0.099	(0.099)	-0.055	(0.150)
Acres	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
FarmInc	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
Crops	0.000	(0.001)	0.000	(0.001)	-0.008 **	(0.003)
Profitability	0.000 ***	(0.000)	0.000 **	(0.000)	-0.002	(0.057)
CNT	----	(0.000)	0.000	(0.000)	0.001	(0.059)
CCRot	0.000 *	(0.000)	0.000	(0.001)	0.000	(0.059)
CCrop	0.001	(0.148)	----	(0.000)	0.317 *	(0.174)
VRA	0.459 **	(0.179)	0.000	(0.036)	----	(0.000)
Risk	0.082	(0.083)	0.185 *	(0.099)	0.325 **	(0.142)
Stewardship	0.008	(0.070)	-0.074	(0.087)	-0.253 *	(0.135)
Innovators	-0.166 **	(0.077)	-0.240 **	(0.097)	-0.478 ***	(0.172)
Western	0.102	(0.112)	0.387 **	(0.166)	0.838 **	(0.404)
Central	0.056	(0.086)	-0.014	(0.103)	0.097	(0.143)
σ	0.326 ***	(0.018)	0.315 ***	(0.025)	0.428 ***	(0.044)
λ	0.033	(0.022)	0.021	(0.003)	0.020	(0.035)
p	3.068 ***	(0.168)	3.170 ***	(0.255)	2.335 ***	(0.238)
----- Fit Statistics -----						
No. observations		223		233		232
Log likelihood function		-121.2		-107.5		-98.7
AIC		274.3		247.0		229.3

*, **, *** statistically significant at the 1%, 5% and 10% level.

Risk aversion was found to delay the adoption of cover crops and VRA of inputs. It has been previously suggested that risk averse farmers may find it optimal to delay adoption to avoid the cost of learning. Risk aversion was not found to significantly affect the speed of adoption of continuous no-till. Similar to the findings in the first essay, this result could indicate that no-till practices are not seen as a risk increasing practice, and risk aversion does not slow the speed of adoption. As expected, farmers who considered themselves innovators adopt the three conservation practices at a faster rate than their counterparts.

The speed of adoption of cover crops and VRA of inputs in the western region of Kansas was found to be slower than in the eastern part of the state. Differences in the time of adoption across regions could indicate differences in climatic and soil conditions, as well as the profitability of the practices. In cases such as with the adoption of VRA of inputs, this could be related to the availability of custom options for precision services. A slower rate in the adoption of cover crops in the western region of Kansas could be the result of dryer weather. During the workshops, some farmers expressed concern about the use of water by cover crops and the availability of water for subsequent cash crops.

The speed at which conservation practices are adopted are subject to various factors as the results of this study suggest. While some factors cannot be controlled, information and knowledge generation are important sources of change. For farmers who are not innovators, knowledge acquisition is an important step and precedes their decision to adopt (Jabbar et al., 2003). It has been suggested that the slow rate of adoption for some practices could be related to slow rates of information acquisition (Fischer et al., 1996). Hence, extension plays an important role, not only in the levels of adoption, but also in the time of adoption. For practices with a

potential to provide large environmental benefits to society, a critical role for extension services then may be to help accelerate the rate of adoption of these practices (Marsh et al., 2000).

In addition, since farmers may delay the adoption of conservation practices until they find it optimal, an important element to conservation efforts could be helping farmers to adapt practices to the conditions of their farming operation. Education efforts could focus on providing farmers with tools to successfully adapt conservation practices in a way that the perceived risks can be mitigated and synergies in the cropping system can be explored.

4.5 Conclusions

This study examined the factors affecting the timing of adoption of continuous no-till, cover crops, and variable rate application of (VRA) of inputs for Kansas farmers to gain insight regarding the time-path diffusion of these conservation cropping practices since their introduction into the agricultural community. A duration analysis was used to account for the dynamics of adoption and changing factors that affect farmer's likelihood of adoption. Some of the factors examined are profitability factors, farmers' demographics, farm and farm management characteristics, attitudinal factors, and geography.

Findings in this study suggest that the adoption of certain practices delay the adoption of other conservation practices. For example, the adoption of conservation crop rotation and VRA of inputs were found to delay the adoption of continuous no-till, and the adoption of cover crops delayed the adoption of VRA of inputs. In addition, the findings in this study suggest that risk aversion is not a significant factor delaying the speed of adoption of continuous no-till. Similar to the first paper, it is possible that farmers do not see no-till as a risky practice, thus risk aversion

may not affect its adoption or speed of adoption. However, risk aversion was found to delay the adoption of cover crops and VRA of inputs. In addition, the results in this study suggest that farmers who considered themselves innovators adopt the three conservation practices at a faster rate than their counterparts. Given that profitability factors and risk aversion seem to be important factors delaying the adoption of cover crops and VRA of inputs, information about the benefits obtained by these practices and how they may mitigate soil degradation and/or may increase profits may be an important message to deliver by extension educators.

4.6 Limitations and future research

Given the cross section nature of the data used in this study, the timing of adoption was modeled under the assumption that some of the factors measured at the time of the survey were the same at the time of adoption, which can be a strong assumption for some of the factors evaluated. For example, the size of the operation may have significantly changed since the date farmers started operating their farms to the date they adopted the conservation practice and finally to the date the survey data was collected. It could be argued, for example, that operational size may have increased over time. However, the time of adoption in this study is modeled under the assumption that farmers are operating at the same scale over time. This is an important issue for future research. A natural extension to this study is to include time-varying covariates to evaluate how changing factors affect the point in time at which farmers decide to adopt new conservation practices. Obtaining such data, however, can be difficult if the researcher does not have access to historical data at the farm level. If the data is collected from farmers it can be unreliable if based on recall (Burton et al., 2003).

References

- Abdulai, A., and W.E. Huffman "The diffusion of new agricultural technologies: The case of crossbred-cow technology in Tanzania." *American Journal of Agricultural Economics* 87 (2005):645-59.
- Adrian, A.M., S.H. Norwood, and P.L. Mask "Producers' perceptions and attitudes toward precision agriculture technologies." *Computers and Electronics in Agriculture* 48 (2005):256-71.
- Alcon, F., M.D. de Miguel, and M. Burton "Duration analysis of adoption of drip irrigation technology in southeastern Spain." *Technological Forecasting and Social Change* 78 (2011):991-1001.
- Au, Y.A., and R.J. Kauffman "What do you know? Rational expectations in information technology adoption and investment." *Journal of Management Information Systems* 20 (2003):49-76.
- Baumgart-Getz, A., L.S. Prokopy, and K. Floress "Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature." *Journal of Environmental Management* 96 (2012):17-25.
- Belknap, J., and W.E. Saupe "Farm family resources and the adoption of no-plow tillage in Southwestern Wisconsin." *North Central Journal of Agricultural Economics* 10 (1988):13-23.
- Bergtold, J.S., and J.J. Molnar "Limited access to conservation: Limited-resource farmer participation in the conservation security program in the southeast." *Journal of Agricultural & Applied Economics* 42 (2010):211.
- Bosch, D.J., and J.W. Pease "Economic risk and water quality protection in agriculture." *Review of Agricultural Economics* 22 (2000):438-63.
- Bultena, G.L., and E.O. Hoiberg "Factors affecting farmers' adoption of conservation tillage." *Journal of Soil and Water Conservation* 38 (1983):281-4.
- Burton, M., D. Rigby, and T. Young "Modelling the adoption of organic horticultural technology in the UK using Duration Analysis." *Australian Journal of Agricultural and Resource Economics* 47 (2003):29-54.
- Cattaneo, A. "The pursuit of efficiency and its unintended consequences: contract withdrawals in the environmental quality incentives program." *Review of Agricultural Economics* 25 (2003):449-69.
- Chatterjee, R.A., and J. Eliashberg "The innovation diffusion process in a heterogeneous population: A micromodeling approach." *Management Science* 36 (1990):1057-79.

- D'Emden, F.H., R.S. Llewellyn, and M.P. Burton "Factors influencing adoption of conservation tillage in Australian cropping regions*." *Australian Journal of Agricultural and Resource Economics* 52 (2008):169-82.
- Daberkow, S.G., and W.D. McBride "Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US." *Precision agriculture* 4 (2003):163-77.
- Dadi, L., M. Burton, and A. Ozanne "Duration analysis of technological adoption in Ethiopian agriculture." *Journal of Agricultural Economics* 55 (2004):613-31.
- Davey, K.A., and W.H. Furtan "Factors that affect the adoption decision of conservation tillage in the prairie region of Canada." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 56 (2008):257-75.
- D'Emden, F.H., R.S. Llewellyn, and M.P. Burton "Adoption of conservation tillage in Australian cropping regions: an application of duration analysis." *Technological Forecasting and Social Change* 73 (2006):630-47.
- Derpsch, R. "History of crop production, with and without tillage." *Leading Edge* 3 (2004):150-4.
- Derpsch, R., T. Friedrich, A. Kassam, and H. Li "Current status of adoption of no-till farming in the world and some of its main benefits." *International Journal of Agricultural and Biological Engineering* 3 (2010):1-25.
- Doraszelski, U. "Innovations, improvements, and the optimal adoption of new technologies." *Journal of Economic Dynamics and Control* 28 (2004):1461-80.
- Feder, G., and D.L. Umali "The adoption of agricultural innovations: a review." *Technological Forecasting and Social Change* 43 (1993):215-39.
- Finger, R., and N. El Benni "Farmers' adoption of extensive wheat production—Determinants and implications." *Land Use Policy* 30 (2013):206-13.
- Fischer, A., A. Arnold, and M. Gibbs "Information and the speed of innovation adoption." *American Journal of Agricultural Economics* 78 (1996):1073-81.
- Fuglie, K.O., and C.A. Kascak "Adoption and diffusion of natural-resource-conserving agricultural technology." *Review of Agricultural Economics* 23 (2001):386-403.
- Ghadim, A.K.A., and D.J. Pannell "A conceptual framework of adoption of an agricultural innovation." *Agricultural Economics* 21 (1999):145-54.
- Ghadim, A.K.A., D.J. Pannell, and M.P. Burton "Risk, uncertainty, and learning in adoption of a crop innovation." *Agricultural Economics* 33 (2005):1-9.

- Gould, B.W., W.E. Saupe, and R.M. Klemme "Conservation tillage: the role of farm and operator characteristics and the perception of soil erosion." *Land Economics* (1989):167-82.
- Green, G., D. Sunding, D. Zilberman, and D. Parker "Explaining irrigation technology choices: a microparameter approach." *American Journal of Agricultural Economics* 78 (1996):1064-72.
- Greene, W.H. *Econometric Analysis*, 7th ed. Upper Saddle River, New Jersey: Pearson Prentice Hall., 2012.
- Greiner, R., L. Patterson, and O. Miller "Motivations, risk perceptions and adoption of conservation practices by farmers." *Agricultural Systems* 99 (2009):86-104.
- Hoppe, H.C. "The timing of new technology adoption: theoretical models and empirical evidence." *The Manchester School* 70 (2002):56-76.
- Hudson, D., and D. Hite "Producer willingness to pay for precision application technology: Implications for government and the technology industry." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 51 (2003):39-53.
- Jabbar, M.A., M.M. Saleem, S. Gebreselassie, and H. Beyene "Role of knowledge in the adoption of new agricultural technologies: an approach and an application." *International Journal of Agricultural Resources, Governance and Ecology* 2 (2003):312-27.
- Jaffe, A.B., R.G. Newell, and R.N. Stavins "Environmental policy and technological change." *Environmental and Resource Economics* 22 (2002):41-70.
- Kalaitzandonakes, N.G., and M.J. Monson "An analysis of potential conservation effort of CRP participants in the state of Missouri: A latent variable approach." *Journal of Agricultural and Applied Economics* 26 (1994):
- Kalbfleisch, J.D., and R.L. Prentice *The statistical analysis of failure time data* John Wiley & Sons, 2011.
- Kiefer, N.M. "Economic duration data and hazard functions." *Journal of Economic Literature* 26 (1988):646-79.
- Knowler, D., and B. Bradshaw "Farmers' adoption of conservation agriculture: A review and synthesis of recent research." *Food Policy* 32 (2007):25-48.
- Krause, M.A., and J.R. Black "Optimal adoption strategies for no-till technology in Michigan." *Review of Agricultural Economics* 17 (1995):299-310.
- Lambert, D.M., P. Sullivan, R. Claassen, and L. Foreman "Profiles of US farm households adopting conservation-compatible practices." *Land Use Policy* 24 (2007):72-88.

- Lancaster, T. *The econometric analysis of transition data* Cambridge university press, 1992.
- Larson, J.A., R.K. Roberts, B.C. English, S.L. Larkin, M.C. Marra, S.W. Martin, K.W. Paxton, and J.M. Reeves "Factors affecting farmer adoption of remotely sensed imagery for precision management in cotton production." *Precision Agriculture* 9 (2008):195-208.
- Llewellyn, R.S. "Information quality and effectiveness for more rapid adoption decisions by farmers." *Field Crops Research* 104 (2007):148-56.
- Lynne, G.D., J.S. Shonkwiler, and L.R. Rola "Attitudes and farmer conservation behavior." *American Journal of Agricultural Economics* 70 (1988):12-9.
- Ma, S., S.M. Swinton, F. Lupi, and C. Jolejole-Foreman "Farmers' Willingness to Participate in Payment-for-Environmental-Services Programmes." *Journal of Agricultural Economics* 63 (2012):604-26.
- Marra, M., D.J. Pannell, and A. Abadi Ghadim "The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?" *Agricultural Systems* 75 (2003):215-34.
- Marsh, S., D. Pannell, and R. Lindner "The impact of agricultural extension on adoption and diffusion of lupins as a new crop in Western Australia." *Animal Production Science* 40 (2000):571-83.
- Murage, A., G. Obare, J. Chianu, D. Amudavi, J. Pickett, and Z. Khan "Duration analysis of technology adoption effects of dissemination pathways: a case of 'push-pull' technology for control of striga weeds and stemborers in Western Kenya." *Crop Protection* 30 (2011):531-8.
- Oostendorp, R.H., and F. Zaal "Land acquisition and the adoption of soil and water conservation techniques: a duration analysis for Kenya and the Philippines." *World Development* 40 (2012):1240-54.
- Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson "Understanding and promoting adoption of conservation practices by rural landholders." *Changing Land Management: Adoption of New Practices by Rural Landholders* (2011):11.
- "Understanding and promoting adoption of conservation practices by rural landholders." *Animal Production Science* 46 (2006):1407-24.
- Prokopy, L., K. Floress, D. Klotthor-Weinkauff, and A. Baumgart-Getz "Determinants of agricultural best management practice adoption: evidence from the literature." *Journal of Soil and Water Conservation* 63 (2008):300-11.
- Rahm, M.R., and W.E. Huffman "The adoption of reduced tillage: the role of human capital and other variables." *American Journal of Agricultural Economics* 66 (1984):405-13.

- Robertson, M., R. Llewellyn, R. Mandel, R. Lawes, R. Bramley, L. Swift, N. Metz, and C. O'Callaghan "Adoption of variable rate fertiliser application in the Australian grains industry: status, issues and prospects." *Precision Agriculture* 13 (2012):181-99.
- Robison, L.J., P.J. Barry, J.B. Kliebenstein, and G.F. Patrick "Risk attitudes: concepts and measurement approaches." *Risk Management in Agriculture*. P. Barry, ed., pp. 3-30. Ames IA: Iowa State University Press, 1984.
- Sassenrath, G., P. Heilman, E. Luschei, G. Bennett, G. Fitzgerald, P. Klesius, W. Tracy, J. Williford, and P. Zimba "Technology, complexity and change in agricultural production systems." *Renewable Agriculture and Food Systems* 23 (2008):285-95.
- Singer, J., S. Nusser, and C. Alf "Are cover crops being used in the US corn belt?" *Journal of Soil and Water Conservation* 62 (2007):353-8.
- Skaggs, R.K., R. Kirksey, and W.M. Harper "Determinants and implications of post-CRP land use decisions." *Journal of Agricultural and Resource Economics* (1994):299-312.
- Soule, M.J., A. Tegene, and K.D. Wiebe "Land tenure and the adoption of conservation practices." *American Journal of Agricultural Economics* 82 (2000):993-1005.
- Taylor, J., and B. Whelan "A general introduction to precision agriculture." *Australian Center for Precision Agriculture* (2005):
- Triplett, G., and W.A. Dick "No-tillage crop production: a revolution in agriculture!" *Agronomy Journal* 100 (2008):S,153-S-165.
- Vitale, J., C. Godsey, J. Edwards, and R. Taylor "The adoption of conservation tillage practices in Oklahoma: Findings from a producer survey." *Journal of Soil and Water Conservation* 66 (2011):250-64.
- Abdulai, A. and W.E. Huffman. 2005. The diffusion of new agricultural technologies: The case of crossbred-cow technology in tanzania. *Am. J. Agric. Econ.* 87:645-659.
- Adrian, A.M., S.H. Norwood and P.L. Mask. 2005. Producers' perceptions and attitudes toward precision agriculture technologies. *Comput. Electron. Agric.* 48:256-271.
- Aimin, H. 2010. Uncertainty, risk aversion and risk management in agriculture. *Agriculture and Agricultural Science Procedia* 1:152-156.
- Akter, S., J. Bennett and M.B. Ward. 2012. Climate change scepticism and public support for mitigation: Evidence from an australian choice experiment. *Global Environ. Change* 22:736-745.
- Alcon, F., M.D. de Miguel and M. Burton. 2011. Duration analysis of adoption of drip irrigation technology in southeastern spain. *Technological Forecasting and Social Change* 78:991-1001.

- Anaele, A. and U. Bishnoi. 1992. Effects of tillage, weed control method and row spacing on soybean yield and certain soil properties. *Soil Tillage Res.* 23:333-340.
- Anderson, J.R. and J.L. Dillon. 1992. Risk analysis in dryland farming systems. Food & Agriculture Org., .
- Aneja, V.P., W.H. Schlesinger and J.W. Erisman. 2009. Effects of agriculture upon the air quality and climate: Research, policy, and regulations. *Environ. Sci. Technol.* 43:4234-4240.
- Antle, J., S. Capalbo, S. Mooney, E. Elliott and K. Paustian. 2003. Spatial heterogeneity, contract design, and the efficiency of carbon sequestration policies for agriculture. *J. Environ. Econ. Manage.* 46:231-250.
- Antle, J.M. and B. Diagana. 2003. Creating incentives for the adoption of sustainable agricultural practices in developing countries: The role of soil carbon sequestration. *Am. J. Agric. Econ.* 85:1178-1184.
- Au, Y.A. and R.J. Kauffman. 2003. What do you know? rational expectations in information technology adoption and investment. *J. Manage. Inf. Syst.* 20:49-76.
- Batte, M.T. 2000. Factors influencing the profitability of precision farming systems. *J. Soil Water Conserv.* 55:12-18.
- Batte, M.T. and M.W. Arnholt. 2003. Precision farming adoption and use in ohio: Case studies of six leading-edge adopters. *Comput. Electron. Agric.* 38:125-139.
- Baumgart-Getz, A., L.S. Prokopy and K. Floress. 2012. Why farmers adopt best management practice in the united states: A meta-analysis of the adoption literature. *J. Environ. Manage.* 96:17-25.
- Beal, D.J. 1996. Emerging issues in risk management in farm firms. *Review of Marketing and Agricultural Economics* 64:.
- Belknap, J. and W.E. Saupe. 1988. Farm family resources and the adoption of no-plow tillage in southwestern wisconsin. *North Central Journal of Agricultural Economics* 10:13-23.
- Ben-Akiva, M. and J. Swait. 1986. The akaike likelihood ratio index. *Transportation Science* 20:133-136.
- Ben-Akiva, M.E. and S.R. Lerman. 1985. Discrete choice analysis: Theory and application to travel demand. MIT press, .
- Bergtold, J.S. and J.J. Molnar. 2010. Limited access to conservation: Limited-resource farmer participation in the conservation security program in the southeast. *Journal of Agricultural & Applied Economics* 42:211.

- Bergtold, J.S., P.A. Duffy, D. Hite and R.L. Raper. 2012. Demographic and management factors affecting the adoption and perceived yield benefit of winter cover crops in the southeast. *Journal of Agricultural and Applied Economics* 44:99-116.
- Bhat, C.R. 1998. Accommodating flexible substitution patterns in multi-dimensional choice modeling: Formulation and application to travel mode and departure time choice. *Transportation Research Part B: Methodological* 32:455-466.
- Biermacher, J.T., B.W. Brorsen, F.M. Epplin, J.B. Solie and W.R. Raun. 2009. The economic potential of precision nitrogen application with wheat based on plant sensing. *Agricultural Economics* 40:397-407.
- Blanco-Canqui, H., L. Stone, A.J. Schlegel, D. Lyon, M. Vigil, M. Mikha, P. Stahlman and C. Rice. 2009. No-till induced increase in organic carbon reduces maximum bulk density of soils. *Soil Sci. Soc. Am. J.* 73:1871-1879.
- Blevins, R., M. Smith, G. Thomas and W. Frye. 1983. Influence of conservation tillage on soil properties. *J. Soil Water Conserv.* 38:301-305.
- Bockus, W. and J. Shroyer. 1998. The impact of reduced tillage on soilborne plant pathogens. *Annu. Rev. Phytopathol.* 36:485-500.
- Bosch, D.J. and J.W. Pease. 2000. Economic risk and water quality protection in agriculture. *Review of Agricultural Economics* 22:438-463.
- Brewer, M.J., R.J. Hoard, J.N. Landis and L.E. Elworth. 2004. The case and opportunity for public-supported financial incentives to implement integrated pest management. *J. Econ. Entomol.* 97:1782-1789.
- Bultena, G.L. and E.O. Hoiberg. 1983. Factors affecting farmers' adoption of conservation tillage. *J. Soil Water Conserv.* 38:281-284.
- Burghart, D.R., T.A. Cameron and G.R. Gerdes. 2007. Valuing publicly sponsored research projects: Risks, scenario adjustments, and inattention. *J. Risk Uncertainty* 35:77-105.
- Burton, M., D. Rigby and T. Young. 2003. Modelling the adoption of organic horticultural technology in the UK using duration analysis. *Aust. J. Agric. Resour. Econ.* 47:29-54.
- Campbell, C., F. Selles, G. Lafond and R. Zentner. 2001. Adopting zero tillage management: Impact on soil C and N under long-term crop rotations in a thin black chernozem. *Can. J. Soil Sci.* 81:139-148.
- Cardina, J., C.P. Herms and D.J. Doohan. 2009. Crop rotation and tillage system effects on weed seedbanks.
- Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecol. Appl.* 8:559-568.

- Caswell, M. and D. Zilberman. 1985. The choices of irrigation technologies in california. *Am. J. Agric. Econ.* 67:224-234.
- Cattaneo, A. 2003. The pursuit of efficiency and its unintended consequences: Contract withdrawals in the environmental quality incentives program. *Review of Agricultural Economics* 25:449-469.
- Chan, K. and D. Heenan. 1996. The influence of crop rotation on soil structure and soil physical properties under conventional tillage. *Soil Tillage Res.* 37:113-125.
- Chatterjee, R.A. and J. Eliashberg. 1990. The innovation diffusion process in a heterogeneous population: A micromodeling approach. *Management Science* 36:1057-1079.
- Chouinard, H.H., T. Paterson, P.R. Wandschneider and A.M. Ohler. 2008. Will farmers trade profits for stewardship? heterogeneous motivations for farm practice selection. *Land Econ.* 84:66-82.
- Claassen, R., A. Cattaneo and R. Johansson. 2008. Cost-effective design of agri-environmental payment programs: US experience in theory and practice. *Ecol. Econ.* 65:737-752.
- Clark, A. 2008. Managing cover crops profitably. DIANE Publishing, .
- Comito, J., J. Wolseth and L.W. Morton. 2013. The state's role in water quality: Soil and water conservation district commissioners and the agricultural status quo. *Hum. Organ.* 72:44-54.
- Cooper, J.C. 2003. A joint framework for analysis of agri-environmental payment programs. *Am. J. Agric. Econ.* 85:976-987.
- Cooper, J.C. 1997. Combining actual and contingent behavior data to model farmer adoption of water quality protection practices. *J. Agric. Resour. Econ.* 22:30-43.
- Cooper, J.C. and G. Signorello. 2008. Farmer premiums for the voluntary adoption of conservation plans. *J. Environ. Plann. Manage.* 51:1-14.
- Cooper, J.C. and R.W. Keim. 1996. Incentive payments to encourage farmer adoption of water quality protection practices. *Am. J. Agric. Econ.* 78:54-64.
- D'Emden, F.H., R.S. Llewellyn and M.P. Burton. 2008. Factors influencing adoption of conservation tillage in australian cropping regions*. *Aust. J. Agric. Resour. Econ.* 52:169-182.
- Daberkow, S.G. and W.D. McBride. 2003. Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture* 4:163-177.
- Dadi, L., M. Burton and A. Ozanne. 2004. Duration analysis of technological adoption in ethiopian agriculture. *Journal of Agricultural Economics* 55:613-631.

- Daniel, J., A. Abaye, M. Alley, C. Adcock and J. Maitland. 1999. Winter annual cover crops in a virginia no-till cotton production system: II. cover crop and tillage effects on soil moisture, cotton yield, and cotton quality. *J.Cotton Sci* 3:84-91.
- Davey, K.A. and W.H. Furtan. 2008. Factors that affect the adoption decision of conservation tillage in the prairie region of canada. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 56:257-275.
- De Pinto, A., M. Magalhaes and C. Ringler. 2010. Potential of carbon markets for small farmers. IFPRI Discussion Papers, International Food Policy Research Institute (IFPRI) 1004:.
- DeJong-Hughes, J. and J. Vetsch. 2007. On-farm comparison of conservation tillage systems for corn following soybeans.
- D'Emden, F.H., R.S. Llewellyn and M.P. Burton. 2006. Adoption of conservation tillage in australian cropping regions: An application of duration analysis. *Technological Forecasting and Social Change* 73:630-647.
- Derpsch, R. 2004. History of crop production, with and without tillage. *Leading Edge* 3:150-154.
- Derpsch, R., T. Friedrich, A. Kassam and H. Li. 2010. Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering* 3:1-25.
- Doraszelski, U. 2004. Innovations, improvements, and the optimal adoption of new technologies. *J. Econ. Dyn. Control* 28:1461-1480.
- Dorfman, J.H. 1996. Modeling multiple adoption decisions in a joint framework. *Am. J. Agric. Econ.* 78:547-557.
- Dupont, D.P. 2010. Cost-Sharing incentive programs for source water protection: The grand river's rural water quality program. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 58:481-496.
- Epplin, F.M., T.F. Tice, A.E. Baquet and S.J. Handke. 1982. Impacts of reduced tillage on operating inputs and machinery requirements. *Am. J. Agric. Econ.* 64:1039-1046.
- Ervin, C.A. and D.E. Ervin. 1982. Factors affecting the use of soil conservation practices: Hypotheses, evidence, and policy implications. *Land Econ.* 58:277-292.
- Espinosa-Goded, M., J. Barreiro-Hurlé and E. Ruto. 2010. What do farmers want from agri-environmental scheme design? A choice experiment approach. *Journal of Agricultural Economics* 61:259-273.
- Fargione, J.E., T.R. Cooper, D.J. Flaspohler, J. Hill, C. Lehman, D. Tilman, T. McCoy, S. McLeod, E.J. Nelson and K.S. Oberhauser. 2009. Bioenergy and wildlife: Threats and opportunities for grassland conservation. *Bioscience* 59:767-777.

- Feder, G. and D.L. Umali. 1993. The adoption of agricultural innovations: A review. *Technological Forecasting and Social Change* 43:215-239.
- Fernandez-Cornejo, J., S. Daberkow and W.D. McBride. 2002. Decomposing the size effect on the adoption of innovations.
- Finger, R. and N. El Benni. 2013. Farmers' adoption of extensive wheat production—Determinants and implications. *Land use Policy* 30:206-213.
- Fischer, A., A. Arnold and M. Gibbs. 1996. Information and the speed of innovation adoption. *Am. J. Agric. Econ.* 78:1073-1081.
- Freeman, J. and C.D. Kolstad. 2006. Prescriptive environmental regulations versus market-based incentives. *Moving to Markets in Environmental Regulation: Lessons from Twenty Years of Experience: Lessons from Twenty Years of Experience* 1.
- Fuglie, K.O. 1999. Conservation tillage and pesticide use in the cornbelt. *Journal of Agricultural and Applied Economics* 31:133-148.
- Fuglie, K.O. and C.A. Kascak. 2001. Adoption and diffusion of natural-resource-conserving agricultural technology. *Review of Agricultural Economics* 23:386-403.
- Galatowitsch, S.M. 2009. Carbon offsets as ecological restorations. *Restor. Ecol.* 17:563-570.
- Galloway, J.N., A.R. Townsend, J.W. Erisman, M. Bekunda, Z. Cai, J.R. Freney, L.A. Martinelli, S.P. Seitzinger and M.A. Sutton. 2008. Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. *Science* 320:889-892.
- Ghadim, A.K.A. and D.J. Pannell. 1999. A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics* 21:145-154.
- Ghadim, A.K.A., D.J. Pannell and M.P. Burton. 2005. Risk, uncertainty, and learning in adoption of a crop innovation. *Agricultural Economics* 33:1-9.
- Gill-Austern, D. 2011. The impact of rising corn prices on the conservation reserve program: An empirical model. *Undergraduate Economic Review* 7:22.
- Glenk, K. and S. Colombo. 2013. Modelling outcome-related risk in choice experiments. *Aust. J. Agric. Resour. Econ.* 57:559-578.
- Glenk, K. and S. Colombo. 2011. How sure can you be? A framework for considering delivery uncertainty in benefit assessments based on stated preference methods. *Journal of Agricultural Economics* 62:25-46.
- Golden, B., J. Bergtold, M. Boland, K. Dhuyvetter, T. Kastens, J. Peterson and S. Staggenborg. 2009. A comparison of select cost-benefit studies on the impacts of HR 2454 on the agriculture sector of the economy. *AgManager.Info*.

- Goldstein, W.M. and H.J. Einhorn. 1987. Expression theory and the preference reversal phenomena. *Psychol. Rev.* 94:236.
- Gonzalez, R. and G. Wu. 1999. On the shape of the probability weighting function. *Cognit. Psychol.* 38:129-166.
- González-Ramírez, J., C.L. Kling and A. Valcu. 2012. An overview of carbon offsets from agriculture. *Annu.Rev.Resour.Econ.* 4:145-160.
- Gould, B.W., W.E. Saupe and R.M. Klemme. 1989. Conservation tillage: The role of farm and operator characteristics and the perception of soil erosion. *Land Econ.* 167-182.
- Grandy, A., G. Robertson and K. Thelen. 2006. Do productivity and environmental trade-offs justify periodically cultivating no-till cropping systems? *Agron. J.* 98:1377-1383.
- Green, G., D. Sunding, D. Zilberman and D. Parker. 1996. Explaining irrigation technology choices: A microparameter approach. *Am. J. Agric. Econ.* 78:1064-1072.
- Greene, W.H. 2012. *Econometric analysis*. Pearson Prentice Hall., Upper Saddle River, New Jersey.
- Greiner, R., L. Patterson and O. Miller. 2009a. Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems* 99:86-104.
- Greiner, R., L. Patterson and O. Miller. 2009b. Motivations, risk perceptions and adoption of conservation practices by farmers. *Agricultural Systems* 99:86-104.
- Hamilton, K., M. Sjardin, A. Shapiro and T. Marcello. 2009. Fortifying the foundation: State of the voluntary carbon markets 2009. *Fortifying the Foundation: State of the Voluntary Carbon Markets 2009*.
- Hardaker, J.B., R.B. Huirne, J.R. Anderson and G. Lien. 2004. *Coping with risk in agriculture*. CABI publishing, .
- Havlin, J., D. Kissel, L. Maddux, M. Claassen and J. Long. 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. *Soil Sci. Soc. Am. J.* 54:448-452.
- Heer, W.F. and E.G. Krenzer Jr. 1989. Soil water availability for spring growth of winter wheat *Triticum aestivum* L. as influenced by early growth and tillage. *Soil Tillage Res.* 14:185-196.
- Helmets, G.A., M.R. Langemeier and J. Atwood. 1986. An economic analysis of alternative cropping systems for east-central nebraska. *Am. J. Alternative Agric.* 1:153-158.
- Hensher, D.A., W.H. Greene and Z. Li. 2011. Embedding risk attitude and decision weights in non-linear logit to accommodate time variability in the value of expected travel time savings. *Transportation Research Part B: Methodological* 45:954-972.

- Hensher, D.A., J.M. Rose and W.H. Greene. 2005. *Applied choice analysis: A primer*. Cambridge University Press, .
- Hoppe, H.C. 2002. The timing of new technology adoption: Theoretical models and empirical evidence. *The Manchester School* 70:56-76.
- Hudson, D. and D. Hite. 2003. Producer willingness to pay for precision application technology: Implications for government and the technology industry. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 51:39-53.
- Humphrey, S.J. and A. Verschoor. 2004. The probability weighting function: Experimental evidence from uganda, india and ethiopia. *Economics Letters* 84:419-425.
- Isik, M. and W. Yang. 2004. An analysis of the effects of uncertainty and irreversibility on farmer participation in the conservation reserve program. *J. Agric. Resour. Econ.* 29:242-259.
- Jabbar, M.A., M.M. Saleem, S. Gebreselassie and H. Beyene. 2003. Role of knowledge in the adoption of new agricultural technologies: An approach and an application. *Int. J. Agric. Resour. , Governance Ecol.* 2:312-327.
- Jaenicke, E.C., D.L. Frechette and J.A. Larson. 2003. Estimating production risk and inefficiency simultaneously: An application to cotton cropping systems. *J. Agric. Resour. Econ.* 28:540-557.
- Jaffe, A.B., R.G. Newell and R.N. Stavins. 2002. Environmental policy and technological change. *Environmental and Resource Economics* 22:41-70.
- Johnson, D., S. Ambrose, T. Bassett, M. Bowen, D. Crummey, J. Isaacson, D. Johnson, P. Lamb, M. Saul and A. Winter-Nelson. 1997. Meanings of environmental terms. *J. Environ. Qual.* 26:581-589.
- Just, R.E. 2003. Risk research in agricultural economics: Opportunities and challenges for the next twenty-five years. *Agricultural Systems* 75:123-159.
- Kahneman, D. and A. Tversky. 1979. Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society* 47:263-291.
- Kalaitzandonakes, N.G. and M.J. Monson. 1994. An analysis of potential conservation effort of CRP participants in the state of missouri: A latent variable approach. *Journal of Agricultural and Applied Economics* 26:.
- Kalbfleisch, J.D. and R.L. Prentice. 2011. *The statistical analysis of failure time data*. John Wiley & Sons, .
- Kaval, P. 2004. The profitability of alternative cropping systems: A review of the literature. *J. Sustainable Agric.* 23:47-65.

- Kiefer, N.M. 1988. Economic duration data and hazard functions. *Journal of Economic Literature* 26:646-679.
- Kim, S., J.M. Gillespie and K.P. Paudel. 2005. The effect of socioeconomic factors on the adoption of best management practices in beef cattle production. *J. Soil Water Conserv.* 60:111-120.
- Kim, S. and B.E. Dale. 2008. Effects of nitrogen fertilizer application on greenhouse gas emissions and economics of corn production. *Environ. Sci. Technol.* 42:6028-6033.
- Kladivko, E.J. 2001. Tillage systems and soil ecology. *Soil Tillage Res.* 61:61-76.
- Knowler, D. and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32:25-48.
- Kotchen, M.J. and E.T. Mansur. 2014. How stringent are the US EPA's proposed carbon pollution standards for new power plants? *Review of Environmental Economics and Policy*.
- Krause, M.A. and J.R. Black. 1995. Optimal adoption strategies for no-till technology in michigan. *Review of Agricultural Economics* 17:299-310.
- Kumbhakar, S.C. 2002. Specification and estimation of production risk, risk preferences and technical efficiency. *Am. J. Agric. Econ.* 84:8-22.
- Kurkalova, L., C. Kling and J. Zhao. 2006. Green subsidies in agriculture: Estimating the adoption costs of conservation tillage from observed behavior. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 54:247-267.
- Kushwaha, C., S. Tripathi and K. Singh. 2001. Soil organic matter and water-stable aggregates under different tillage and residue conditions in a tropical dryland agroecosystem. *Applied Soil Ecology* 16:229-241.
- Lal, R. 1999. Long-term tillage and wheel traffic effects on soil quality for two central ohio soils. *J. Sustainable Agric.* 14:67-84.
- Lal, R. 1993. Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Soil Tillage Res.* 27:1-8.
- Lamb, D.W., P. Frazier and P. Adams. 2008. Improving pathways to adoption: Putting the right P's in precision agriculture. *Comput. Electron. Agric.* 61:4-9.
- Lambert, D.M., P. Sullivan, R. Claassen and L. Foreman. 2007. Profiles of US farm households adopting conservation-compatible practices. *Land use Policy* 24:72-88.
- Lancaster, K.J. 1966. A new approach to consumer theory. *The Journal of Political Economy* 74:132-157.

- Lancaster, T. 1992. The econometric analysis of transition data. Cambridge university press, .
- Larson, J., R. Roberts, E. Jaenicke and D. Tyler. 2001a. Profit-maximizing nitrogen fertilization rates for alternative tillage and winter cover systems. *J.Cotton Sci* 5:156-168.
- Larson, J.A., E.C. Jaenicke, R.K. Roberts and D.D. Tyler. 2001b. Risk effects of alternative winter cover crop, tillage, and nitrogen fertilization systems in cotton production. *Journal of Agricultural and Applied Economics* 33:445-458.
- Larson, J.A., R.K. Roberts, B.C. English, S.L. Larkin, M.C. Marra, S.W. Martin, K.W. Paxton and J.M. Reeves. 2008. Factors affecting farmer adoption of remotely sensed imagery for precision management in cotton production. *Precision Agriculture* 9:195-208.
- Lattimore, P.K., J.R. Baker and A.D. Witte. 1992. The influence of probability on risky choice: A parametric examination. *Journal of Economic Behavior & Organization* 17:377-400.
- Li, Z. and D.A. Hensher. 2013. Behavioural implications of preferences, risk attitudes and beliefs in modelling risky travel choice with travel time variability. *Transportation* 40:505-523.
- Li, Z., A. Tirachini and D.A. Hensher. 2012. Embedding risk attitudes in a scheduling model: Application to the study of commuting departure time. *Transportation Science* 46:170-188.
- Li, Z., D.A. Hensher and J.M. Rose. 2010. Willingness to pay for travel time reliability in passenger transport: A review and some new empirical evidence. *Transportation Research Part E: Logistics and Transportation Review* 46:384-403.
- Lichtenberg, E. 2004. Cost-responsiveness of conservation practice adoption: A revealed preference approach. *J. Agric. Resour. Econ.* 29:420-435.
- Llewellyn, R.S. 2007. Information quality and effectiveness for more rapid adoption decisions by farmers. *Field Crops Res.* 104:148-156.
- Llewellyn, R.S., F.H. D'Emden and G. Kuehne. 2012. Extensive use of no-tillage in grain growing regions of australia. *Field Crops Res.* 132:204-212.
- Lodhi, M., R. Bilal and K. Malik. 1987. Allelopathy in agroecosystems: Wheat phytotoxicity and its possible roles in crop rotation. *J. Chem. Ecol.* 13:1881-1891.
- Louviere, J.J., D.A. Hensher and J.D. Swait. 2000. Stated choice methods: Analysis and applications. Cambridge University Press, .
- Lynne, G.D., J.S. Shonkwiler and L.R. Rola. 1988. Attitudes and farmer conservation behavior. *Am. J. Agric. Econ.* 70:12-19.
- Ma, S., S.M. Swinton, F. Lupi and C. Jolejole-Foreman. 2012. Farmers' willingness to participate in Payment-for-Environmental-Services programmes. *Journal of Agricultural Economics* 63:604-626.

- MacCrimmon, K.R. and D.A. Wehrung. 1990. Characteristics of risk taking executives. *Management Science* 36:422-435.
- Maddala, G.S. 1983. *Limited-dependent and qualitative variables in econometrics*. Cambridge university press, .
- March, J.G. and Z. Shapira. 1987. Managerial perspectives on risk and risk taking. *Management Science* 33:1404-1418.
- Marra, M., D.J. Pannell and A. Abadi Ghadim. 2003. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems* 75:215-234.
- Marra, M.C. and G.A. Carlson. 1990. The decision to double crop: An application of expected utility theory using stein's theorem. *Am. J. Agric. Econ.* 72:337-345.
- Marsh, S., D. Pannell and R. Lindner. 2000. The impact of agricultural extension on adoption and diffusion of lupins as a new crop in western australia. *Animal Production Science* 40:571-583.
- McConkey, B., B. Liang, C. Campbell, D. Curtin, A. Moulin, S. Brandt and G. Lafond. 2003. Crop rotation and tillage impact on carbon sequestration in canadian prairie soils. *Soil Tillage Res.* 74:81-90.
- Meyer, J. 2010. Representing risk preferences in expected utility based decision models. *Annals of Operations Research* 176:179-190.
- Mezzatesta, M., D.A. Newburn and R.T. Woodward. 2013. Additionality and the adoption of farm conservation practices. *Land Econ.* 89:722-742.
- Miguez, F.E. and G.A. Bollero. 2005. Review of corn yield response under winter cover cropping systems using meta-analytic methods. *Crop Sci.* 45:2318-2329.
- Morand, H. and P.J. Thomassin. 2005. Changes in quebec cropping practices in response to a carbon offset market: A simulation. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 53:403-424.
- Murage, A., G. Obare, J. Chianu, D. Amudavi, J. Pickett and Z. Khan. 2011. Duration analysis of technology adoption effects of dissemination pathways: A case of 'push-pull' technology for control of striga weeds and stemborers in western kenya. *Crop Protection* 30:531-538.
- Nascente, A.S., Y.C. Li and C.A.C. Crusciol. 2013. Cover crops and no-till effects on physical fractions of soil organic matter. *Soil Tillage Res.* 130:52-57.
- Oostendorp, R.H. and F. Zaal. 2012. Land acquisition and the adoption of soil and water conservation techniques: A duration analysis for kenya and the philippines. *World Dev.* 40:1240-1254.

- Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay and R. Wilkinson. 2011. Understanding and promoting adoption of conservation practices by rural landholders. *Changing Land Management: Adoption of New Practices by Rural Landholders* 11.
- Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Animal Production Science* 46:1407-1424.
- Paustian, K., J. Six, E. Elliott and H. Hunt. 2000. Management options for reducing CO₂ emissions from agricultural soils. *Biogeochemistry* 48:147-163.
- Pennings, J.M. and P. Garcia. 2001. Measuring producers' risk preferences: A global risk-attitude construct. *Am. J. Agric. Econ.* 83:993-1009.
- Peterson, J.M., C.M. Smith, J.C. Leatherman, N.P. Hendricks and J.A. Fox. 2012. The role of contract attributes in purchasing environmental services from landowners. Kansas State University, Kansas.
- Pierce, F.J. and C.W. Rice. 1988. Crop rotation and its impact on efficiency of water and nitrogen use. *Cropping Strategies for Efficient use of Water and Nitrogen* 21-42.
- Pratt, J.W. 1964. Risk aversion in the small and in the large. *Econometrica: Journal of the Econometric Society* 32:122-136.
- Prelec, D. 1998. The probability weighting function. *Econometrica* 66:497-527.
- Prokopy, L., K. Floress, D. Klotthor-Weinkauff and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. *J. Soil Water Conserv.* 63:300-311.
- Rahm, M.R. and W.E. Huffman. 1984. The adoption of reduced tillage: The role of human capital and other variables. *Am. J. Agric. Econ.* 66:405-413.
- Raimbault, B. and T. Vyn. 1991. Crop rotation and tillage effects on corn growth and soil structural stability. *Agron. J.* 83:979-985.
- Reimer, A.P. and L.S. Prokopy. 2014. Farmer participation in US farm bill conservation programs. *Environ. Manage.* 53:318-332.
- Ribaudo, M., C. Greene, L. Hansen and D. Hellerstein. 2010. Ecosystem services from agriculture: Steps for expanding markets. *Ecol. Econ.* 69:2085-2092.
- Ribera, L.A., F. Hons and J.W. Richardson. 2004. An economic comparison between conventional and no-tillage farming systems in burleson county, texas. *Agron. J.* 96:415-424.

- Ridier, A., K. Chaib and C. Roussy. 2012. The adoption of innovative cropping systems under price and production risks: A dynamic model of crop rotation choice. *In* The adoption of innovative cropping systems under price and production risks: A dynamic model of crop rotation choice. EAAE seminar: Price volatility and farm income stabilization: Modelling outcomes and assessing market and policy based response, Feb 2012, Dublin, Ireland. 2012.
- Robbins, A. 2005. Ecosystem services markets.
- Roberts, D.C., T.A. Boyer and J.L. Lusk. 2008. Preferences for environmental quality under uncertainty. *Ecol. Econ.* 66:584-593.
- Robertson, M., R. Llewellyn, R. Mandel, R. Lawes, R. Bramley, L. Swift, N. Metz and C. O'Callaghan. 2012. Adoption of variable rate fertiliser application in the Australian grains industry: Status, issues and prospects. *Precision Agriculture* 13:181-199.
- Robison, L.J., P.J. Barry, J.B. Kliebenstein and G.F. Patrick. 1984. Risk attitudes: Concepts and measurement approaches. p. 3-30. *In* P. Barry (ed.) Risk management in agriculture. Iowa State University Press, Ames IA.
- Rodriguez, J.M., J.J. Molnar, R.A. Fazio, E. Sydnor and M.J. Lowe. 2009. Barriers to adoption of sustainable agriculture practices: Change agent perspectives. *Renewable Agriculture and Food Systems* 24:60-71.
- Rolfe, J. and J. Windle. 2013. Including management policy options in discrete choice experiments: A case study of the Great Barrier Reef. *Canadian Journal of Agricultural Economics/Revue Canadienne D'Agroeconomie* 61:197-215.
- Roth, G.W. 1996. Crop rotations and conservation tillage. 1:1-4.
- Ruto, E. and G. Garrod. 2009. Investigating farmers' preferences for the design of agri-environment schemes: A choice experiment approach. *J. Environ. Plann. Manage.* 52:631-647.
- Saha, A., C.R. Shumway and H. Talpaz. 1994. Joint estimation of risk preference structure and technology using expo-power utility. *Am. J. Agric. Econ.* 76:173-184.
- Saltiel, J., J.W. Bauder and S. Palakovich. 1994. Adoption of sustainable agricultural practices: Diffusion, farm structure, and Profitability. *Rural Sociol.* 59:333-349.
- Sarrantonio, M. and E. Gallandt. 2003. The role of cover crops in North American cropping systems. *J. Crop Prod.* 8:53-74.
- Sassenrath, G., P. Heilman, E. Luschei, G. Bennett, G. Fitzgerald, P. Klesius, W. Tracy, J. Williford and P. Zimba. 2008. Technology, complexity and change in agricultural production systems. *Renewable Agriculture and Food Systems* 23:285-295.

- Sattler, C. and U.J. Nagel. 2010. Factors affecting farmers' acceptance of conservation measures—a case study from north-eastern germany. *Land use Policy* 27:70-77.
- Schimmelpfennig, D. and R. Ebel. 2011. On the doorstep of the information age: Recent adoption of precision agriculture. US Department of Agriculture, Economic Research Service, .
- Shapiro, B.I., B. Wade Brorsen and D.H. Doster. 1992. Adoption of double-cropping soybeans and wheat. *Southern Journal of Agricultural Economics* 24:33-33.
- Singer, J., S. Nusser and C. Alf. 2007. Are cover crops being used in the US corn belt? *J. Soil Water Conserv.* 62:353-358.
- Sitkin, S.B. and A.L. Pablo. 1992. Reconceptualizing the determinants of risk behavior. *Academy of Management Review* 17:9-38.
- Skaggs, R.K., R. Kirksey and W.M. Harper. 1994. Determinants and implications of post-CRP land use decisions. *J. Agric. Resour. Econ.* 299-312.
- Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach and J. Smith. 2008. Greenhouse gas mitigation in agriculture. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 363:789-813.
- Snapp, S., S. Swinton, R. Labarta, D. Mutch, J. Black, R. Leep, J. Nyiraneza and K. O'Neil. 2005. Evaluating cover crops for benefits, costs and performance within cropping system niches. *Agron. J.* 97:322-332.
- Soule, M.J., A. Tegene and K.D. Wiebe. 2000. Land tenure and the adoption of conservation practices. *Am. J. Agric. Econ.* 82:993-1005.
- Stott, H.P. 2006. Cumulative prospect theory's functional menagerie. *J. Risk Uncertainty* 32:101-130.
- Taylor, J. and B. Whelan. 2005. A general introduction to precision agriculture. Australian Center for Precision Agriculture.
- Triplett, G. and W.A. Dick. 2008. No-tillage crop production: A revolution in agriculture! *Agron. J.* 100:S-153-S-165.
- Tversky, A. and D. Kahneman. 1992. Advances in prospect theory: Cumulative representation of uncertainty. *J. Risk Uncertainty* 5:297-323.
- Tyner, W. and F. Taheripour. 2008. Biofuels, policy options, and their implications: Analyses using partial and general equilibrium approaches. *Journal of Agricultural & Food Industrial Organization* 6:.

- Van Houtven, G., F.R. Johnson, V. Kilambi and A.B. Hauber. 2011. Eliciting benefit-risk preferences and probability-weighted utility using choice-format conjoint analysis. *Med. Decis. Making* 31:469-480.
- Varner, B.T., F.M. Epplin and G.L. Strickland. 2011. Economics of no-till versus tilled dryland cotton, grain sorghum, and wheat. *Agron. J.* 103:1329-1338.
- Vellidis, G., B. Ortiz, J. Beasley, R. Hill, H. Henry and H. Brannen. 2013. Using RTK-based GPS guidance for planting and inverting peanuts. p. 357-364. *In* Using RTK-based GPS guidance for planting and inverting peanuts. Precision agriculture'13. Springer, .
- Veronesi, M., F. Chawla, M. Maurer and J. Lienert. 2014. Climate change and the willingness to pay to reduce ecological and health risks from wastewater flooding in urban centers and the environment. *Ecol. Econ.* 98:1-10.
- Visschers, V.H., R.M. Meertens, W.W. Passchier and N.N. De Vries. 2009. Probability information in risk communication: A review of the research literature. *Risk Analysis* 29:267-287.
- Vitale, J., C. Godsey, J. Edwards and R. Taylor. 2011. The adoption of conservation tillage practices in oklahoma: Findings from a producer survey. *J. Soil Water Conserv.* 66:250-264.
- Von Neumann, J. and O. Morgenstern. 1945. Theory of games and economic behavior. *The Bulletin of the American Mathematical Society* 51:498-504.
- Wang, Y., C. Tu, L. Cheng, C. Li, L.F. Gentry, G.D. Hoyt, X. Zhang and S. Hu. 2011. Long-term impact of farming practices on soil organic carbon and nitrogen pools and microbial biomass and activity. *Soil Tillage Res.* 117:8-16.
- Weber, E.U. and R.A. Milliman. 1997. Perceived risk attitudes: Relating risk perception to risky choice. *Management Science* 43:123-144.
- West, T.O. and G. Marland. 2002. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: Comparing tillage practices in the united states. *Agric. , Ecosyst. Environ.* 91:217-232.
- West, T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation. *Soil Sci. Soc. Am. J.* 66:1930-1946.
- Whitten, S.M. and A. Coggan. 2013. Market-based instruments and ecosystem services. *Ecosystem Services in Agricultural and Urban Landscapes* 178-193.
- Williams, J.R., S. Mooney and J.M. Peterson. 2009. What is the carbon market: Is there a final answer? *J. Soil Water Conserv.* 64:27A-35A.

- Williams, J.R., T.W. Roth and M.M. Claassen. 2000. Profitability of alternative production and tillage strategies for dryland wheat and grain sorghum in the central great plains. *J. Soil Water Conserv.* 55:49-56.
- Williams, J.R., M.J. Pacht, K.L. Roozeboom, R.V. Llewelyn, M.M. Claassen, J.S. Bergtold, M.A. Marchant and D.J. Bosch. 2012. Risk analysis of tillage and crop rotation alternatives with winter wheat. *Journal of Agricultural and Applied Economics* 44:561.
- Young, L.M. 2003. Carbon sequestration in agriculture: The US policy context. *Am. J. Agric. Econ.* 85:1164-1170.
- Zeuli, K.A. and J.R. Skees. 2000. Will southern agriculture play a role in a carbon market? *Journal of Agricultural and Applied Economics* 32:235-248.
- Zibilske, L., J. Bradford and J. Smart. 2002. Conservation tillage induced changes in organic carbon, total nitrogen and available phosphorus in a semi-arid alkaline subtropical soil. *Soil Tillage Res.* 66:153-163.