FARM-SCALE ECONOMIC ANALYSIS OF COVER CROP ADOPTION UNDER RISK AVERSION: THE CASE FOR CORN, PEANUT, AND COTTON IN SOUTHEASTERN GEORGIA

by

KELVIN KWADJO BOBBIE

(Under the Direction of Yangxuan Liu and Wesley Porter)

ABSTRACT

Cover crops have been known to provide economic benefits and improve soil health but most farmers are reluctant to adopt them due to the uncertainty around its effects on yield and profitability. This study quantifies the risk of cover crop adoption for corn, peanut, and cotton rotation in Georgia evaluated at these scenarios; no cover crop, single species of Rye, and both single and multi-specie legumes added to Rye. From the results, it was realized that cover crop treatments were associated with lower yields as compared to the no cover crop treatment (Control). Risk averse farmers are likely to favor the Control treatment when considering the distribution of net returns. With the aid of Stochastic efficiency with respect to a function (SERF), the study shows that the most risk efficient cover crop treatment depends on the cash crop to be planted and the risk aversion level of the farmer.

INDEX WORDS: Cover Crop, Adoption, Risk Aversion, Stochastic Efficiency with Respect to a Function (SERF), Risk-efficient, Negative Exponential Utility, Certainty equivalent, Risk Premium.

FARM-SCALE ECONOMIC ANALYSIS OF COVER CROP ADOPTION UNDER RISK AVERSION: THE CASE FOR CORN, PEANUT, AND COTTON IN SOUTHEASTERN GEORGIA

by

KELVIN KWADJO BOBBIE

B.S., Kwame Nkrumah University of Science and Technology, Ghana, 2017

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2024

FARM-SCALE ECONOMIC ANALYSIS OF COVER CROP ADOPTION UNDER RISK AVERSION: THE CASE FOR CORN, PEANUT, AND COTTON IN SOUTHEASTERN GEORGIA

by

KELVIN KWADJO BOBBIE

Major Professors: Yangxuan Liu
Wesley Porter

Committee: Cesar L. Escalante
Gregory Colson

Electronic Version Approved:

Ron Walcott
Vice Provost for Graduate Education and Dean of the Graduate School
The University of Georgia
August 2024

DEDICATION

I dedicate this thesis to my mother and beloved grandmother, Dora Akuamoah Boateng and Felicia Boateng and to my mentor and friend, Dadson Awunyo-Vitor and Emmanuel Mensah Bonsu for their unconditional support and unwavering belief in my potential.

ACKNOWLEDGEMENTS

As I conclude this educational chapter of my life, I would like to acknowledge all those who have contributed greatly to the success of my masters education.

I would to like express my profound gratitude to my major advisor, Dr. Yangxuan Liu, for all the support she has shown me throughout the research process. Her provision of financial support for my research and conference participations, her advice, time and patience over the course of the research, and her dedication to aiding my future endeavors cannot be overstated. Without her guidance, this thesis would not have been successful. I want to acknowledge Dr. Cesar Escalante and Dr. Gregory Colson for their input into this research and their immense support and helpful advice when it came to my doctoral degree application. I also want to acknowledge Dr. Wesley Porter and the team down in Tifton for their hard work which led to the successful completion of the farm experiment especially team members like Mary Logan Tostensen, Mrs. Kaylyn Groce, Mr. Anthony Black and Mr. Peyton Sapp who were also showed patience and made themselves available to answer all questions in order to make this thesis successful.

Finally, I thank my classmates and friends. Your day-to-day camaraderie and support are why I am the student I am today.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Over the years, climate change has had a significant negative influence on agricultural production, resulting in an augmented prevalence of risk and volatility within the agricultural sector. Consequently, these shifts have put the world's food security at risk, particularly in the context of the expanding worldwide population. The heightened risk associated with climate change has spurred policymakers and farmers to actively pursue endeavors intended to improve agricultural production in a sustainable way. A significant strategy regarding reducing the effects of climate change involves the adoption of conservation agriculture. This approach entails the implementation of farming practices like utilizing cover crops and conservation tillage, which serve to safeguard and enhance soil health and fertility while concurrently improving overall agricultural productivity.

According to the Economic Research Service (ERS) of the U.S. Department of Agriculture (2024), the combined contributions of food, agricultural, and associated industries constituted approximately 5.4% of the GDP (Gross Domestic Product) of the U.S, equivalent to approximately US$1.2 trillion. The sector also contributed to about 10.4% of all jobs in the United States, 2.6 million of which are related to work on farms. In Georgia, the combined contribution of food and fibre production, encompassing all directly and indirectly related sectors, amounts to approximately US$ 69.4 billion within the broader context of the US$ 1.1

trillion economy. The Georgia Conservancy (2023) reports that agriculture is the state's largest industry as one in every seven people work in agriculture. The economic activity of Agriculture in Georgia generates an additional 342,430 jobs (Kane, 2022). The significance of the agricultural industry to Georgia and the U.S. is undeniable and hence agricultural sustainability over the long haul is key to the stability of its economy. Among all the row crops cultivated in the state of Georgia, cotton, corn and peanuts are the three most important crops grown as they represent 75.4% of the total value of row crops and forage crops in Georgia (31.1% for corn, 29% for peanuts, and 15.3% for corn) (Kane, 2022). Georgia's commitment to the production of these major row crops is undeniable as the state ranks first nationally in the production of peanuts and second in cotton lint and cotton seed (USDA-NASS, 2020).

Adeux et al. (2021) highlighted that the pursuit of elevated crop yields has led to a substantial dependence on agricultural inputs, notably nitrogen (N) fertilizers and herbicides, coupled with intensive tillage practices. This reliance has, in turn, engendered a diverse array of environmental repercussions, encompassing issues such as water and air contamination, soil erosion, diminished diversity of arable plants, and compromised soil fertility. Consequently, this scenario has prompted the increasing adoption of cover crops as a mitigative measure. Cover crops as the name indicates, are generally legumes or non-legumes/grasses planted to cover the soil to enhance soil health. Specifically, cover crops conserve moisture and improve the soil water table, reduce soil erosion, control weeds and pests and improve carbon sequestration (Adetunji *et al.*, 2020; Koudahe, Allen and Djaman, 2022).

Farmers face a decision between single-specie and various mixtures of multi-species cover crops. The adoption of single-specie cover crops usually depends on the farmers' objectives. Grass covers, for instance, are chosen because of their rapid growth and long-lasting residues they provide, contributing substantial soil cover that gradually decomposes. Conversely, broad-leaf species decompose at a faster rate, facilitating the more rapid release of absorbed nutrients into the environment, making them a potentially preferable choice for certain agricultural producers. Leguminous cover crops, owing to their capacity to fix atmospheric nitrogen in the root nodules, are specifically used in agriculture. Furthermore, certain non-leguminous broadleaves, like radish (Raphanus sativus L.), with their strong tap-root systems, may efficiently permeate both the surface and subsurface compacted layers of soil. Combining different types of broadleaf cover crops, including grass and non-leguminous and leguminous is advocated for its potential to provide several benefits. The rationale behind multispecies cover crop mixes lies on the premise that at least one or a few species will flourish each year and generate enough biomass to suppress weeds and improve soil characteristics (Koudahe, Allen and Djaman, 2022). Although cover crops have shown the ability to enhance environmental conditions and lower the cost of tillage, fertilizer, and irrigation, adoption of cover crops could raise other production costs. There are questions about how different species of cover crops impacts yield as some literature suggests that nitrogen capture and organic matter improvement can increase yield, while others also show that cover cropping might also reduce yields due to nutrient immobilization (Essah et al., 2012; Delgado and Gantzer, 2015). Producers frequently exhibit hesitation to adopt cover crops, primarily due to uncertainties regarding their profitability and the feasibility of implementation. Although cover crop adoption can lower production costs and increase crop yields similar to how leguminous cover crops work and their potential to lower the cost of nitrogen fertilizer, they require additional costs in the form of the establishment of cover crops and termination costs. Because of the uncertainty around these expenses' effects on crop yield and farm profitability, growers are hesitant to adopt cover crops.

1.2 Research Questions

This study quantifies the risk associate with the adoption of cover crops in a three-year rotation involving corn, peanut, and cotton production in Georgia. We examined how different cover crop treatments varied in their net returns for each major crop. Enterprise budgets that include the costs of producing each major crop at the farm level under four cover crop treatments from a 6-year field experiment were evaluated. The four cover crop treatments include a control of no cover crops, single species of rye, mix of rye and crimson clover, and mix of four or more cover crop species. All these cover crop treatments were planted under strip tillage except for the control treatment which was planted under conventional tillage. The following are the research questions that this study seeks to address:

1. How does the adoption of cover crops impact main crop yields in a three-year rotation, involving corn, peanut, and cotton production in Georgia?
2. How does the variability in the distribution net returns differ between alternative cover crop treatments for each major crop in the specified rotation?
3. What is the risk-efficient cover crop treatment for producers engaged in cotton, peanut, and corn rotation in Georgia?

1.3 Research Objectives

This research assesses the impact on profitability of cotton, peanuts, and corn production under single and multi-species cover crop treatments with strip tillage as compared to a treatment with no cover crops coupled with conventional tillage. We seek to determine the economic impact of adopting cover crop with cotton, peanut, and corn rotation. Using enterprise budgets and stochastic efficiency regarding a function, this research aims to determine the most risk-efficient cover crop treatment. This research holds significance for farmers, extension agents, and policy makers, as they help farmers in aligning cover crop choices with their risk preference and aiding policy makers in the effective design of conservation programs.

CHAPTER 2

LITERATURE REVIEW

2.1 Conservation Tillage

The goal of conservation tillage, an agricultural management practice, is to attain both economic and environmental benefits by reducing the frequency or intensity of tillage operations. The literature study delves deeply into the complex relationships between conservation tillage and crop productivity, soil health, and nitrogen management, highlighting both advantages and disadvantages. Although conservation tillage frequently improves yield and soil health, its efficacy varies depending on the crop type, soil properties, and tillage system. Moreover, it may result in increased soil compaction. Farmers' decisions to implement these practices are mostly influenced by economic factors, with possible cost savings and reduced soil erosion being the main advantages. Nonetheless, the benefits of conserving water and soil are frequently outweighed by economic uncertainty. Reduced nitrogen leaching and nitrogen oxide emissions are among the environmental benefits; however, occasionally, these are outweighed by increased ammonia volatilizationThese observations emphasize the necessity of customized conservation tillage practices that take into consideration unique local circumstances in order to optimize its advantages for agriculture and the environment.

Crop scientists believe conservation tillage increases yield, which is one of the main reasons they support it. The effects of conservation tillage on agricultural yields have been the subject of much research, yet the findings are frequently contradictory. According to Jug et al. (2019), conservation tillage generally boosts grain yields and biomass in corn and winter wheat crops. However, the effectiveness of these impacts differs depending on the type of tillage, crop type, and soil composition. To get the most out of these advantages, nitrogen rate optimization is also crucial. In a meta-regression analysis of European studies comparing crop yields under reduced tillage (RT), no-tillage (NT), and conventional tillage (CT), Van Den Putte et al. (2010) found that although conservation tillage may marginally lower yields, these adverse effects can be countered by modifying tillage depth and implementing strategic crop rotations. According to Anapalli et al. (2018), the Root Zone Water Quality Model synthesized data that showed a consistent yield decline in irrigated corn under NT systems as opposed to CT. Studies conducted by Sun et al. (2018) and others have demonstrated that additional soil properties may influence yield fluctuations under conservation tillage. They assessed the effects of NT (No Till), CT (Conservation Tillage), and subsoiling tillage (ST) on crop yield for continuous winter wheat cropping, continuous spring corn cropping, and a combination of the two crops. The study showed that certain tillage techniques, which rely on the cropping system, produce the maximum rates of production in wheat and corn. According to some research, the degree to which conservation tillage improves other aspects of soil health determines how big of an improvement in yields it makes. There is a significant potential for yield improvement through careful tillage management since certain conservation tillage techniques improve soil properties and production in comparison to conventional tillage. (Pramanick et. al., 2022).

Most farmers grow crops that need a lot of nitrogen, such as corn and cotton. It is thought that conservation tillage affects how nitrogen is mobilized in the soil. Chisel Plough Tillage (CPT) and Zero Tillage (ZT) considerably reduce N2O emissions and nitrogen leaching while boosting crop nitrogen uptake and yearly yield, according to Wang et al. (2020). These practices led to a notable increase in soil total nitrogen accumulation and a net decrease in overall nitrogen losses, despite an increase in ammonia (NH3) volatilization. According to these results, CPT and ZT may be able to increase crop production and sustainability by enhancing the removal of nitrogen from crop biomass and reducing nitrogen losses from gaseous emissions and hydrological leaching. The effect of different nitrogen rates on nitrogen use efficiency (NUE) was also investigated by Jug et al. (2019). They specifically noted a general drop in NUE with higher nitrogen rates from N1 (low) to N3 (luxury) for both winter wheat and corn. The study shows that depending on the kind of soil and tillage strategy, winter wheat biomass and grain yield varied from N2 (optimal) to N3 (luxury), even if they increased from N1 (low) to N2 (optimal). The difficulties with no-tillage (NT) systems were also covered by Anapalli et al. (2018), with a focus on how NT systems may result in lower grain yields. Lower rates of nitrogen mineralization brought on by colder soil temperatures, increased nitrogen loss from runoff and deep percolation, and denitrification brought on by higher soil water content are all responsible for the decline. The intricate relationships between crop nutrient dynamics, soil properties, and tillage techniques are highlighted by this analysis.

Soil health refers to the soil's capacity to carry on as a vital living ecosystem that supports people, animals, and plants. The majority of research indicates that conservation tillage enhances a number of soil properties including soil health, although there may be certain drawbacks. Research on the impacts of conservation tillage on winter wheat and corn, such as that conducted by Jug et al. (2019), found that Gleysol soils had the lowest total porosity and considerable soil compaction of the tillage treatments. This suggests that even if conservation tillage may be beneficial in other respects, it may also lead to denser soil formations. In order to compare crop yields under conventional tillage (CT), reduced tillage (RT), and no-tillage (NT) methods in

European studies, Van Den Putte et al. (2010) performed a meta-regression analysis. They found that while conservation agriculture (CA) is successful in reducing soil erosion, there are a number of disadvantages, including higher pest prevalence and improper seed placement. Curiously, conservation tillage approaches work better on clay and sandy soils and in drier climates where these detrimental impacts are less noticeable. Certain conservation tillage techniques, such minimum and zero tillage (ZT), are especially good at breaking the surface compact zone with little disturbance of the soil, improving soil conditions and crop yields while having the least negative effects on the environment (Busari et al., 2015). Page et al. (2013) detailed the chemical and biological alterations brought about by conservation tillage, including alterations to the soil's cation exchange capacity, pH decreases, and alterations to its nutrient availability. Even while there are gains in microbial diversity, biomass, and soil organic carbon, these are occasionally outweighed by the rise in weeds and plant diseases. Lower yields might happen in situations when there are problems like crop diseases, weed growth, nutrient shortages, or poor soil structure.

The advantages of conservation agriculture in reducing water stress and increasing crop yield, particularly in semi-arid areas, have been the subject of several research. Sun et al. (2018) highlight that although there are no appreciable variations in evapotranspiration and soil water storage (SWS) at other times, conservation tillage techniques in the semi-arid Loess Plateau region improve SWS prior to planting and attain high WUE for crops like wheat and corn. According to Anapalli (2018), no-tillage (NT) can lower grain yield because of reduced nitrogen mineralization from lower soil temperatures, higher soil water content, and increased nitrogen loss from deep percolation and runoff. Bhattatrai (2020) finds that modern irrigation scheduling methods, especially the cotton app, are more economical than traditional methods, producing better net returns per acre during dry years and exhibiting variable effectiveness during rainy years. According to Ali et al. (2016), tied-ridging, in particular, is a conservation tillage practice that greatly increases WUE in crops like peanuts, cotton, sorghum, and wheat. Last but not least, Page et al. (2013) describe how conservation tillage enhances the physical characteristics of the soil and, by boosting water infiltration and storage, can increase agricultural production in dry years. When taken as a whole, these studies highlight how modern irrigation methods and conservation tillage can improve agricultural sustainability in water-limited situations.

Different regions have varied reasons for farmers to embrace no-till and conservation agriculture (CA) practices, depending on operational, environmental, and economic considerations. According to Van Den Putte (2010), economic factors—specifically, the reduction in production expenses such as fuel—are the primary motivators for switching to Conservation agriculture (CA) even in the face of yield and profitability uncertainty. Producers are aware of the benefits of no-till agriculture in terms of reducing erosion, but D'Emden (2008) notes that the advantages to short-term crop production—such as improved pre-emergent herbicide efficacy and the ability to seed earlier with less rainfall—influence the practice's adoption. Furthermore, adopting no-till is substantially correlated with consultancies and involvement in agricultural extension initiatives, underscoring the information- and learning-intensive nature of these approaches. Farmers are generally reluctant to convert from conventional to conservation tillage, according to Akancheng and Cornellis (2023), because of financial worries and varying effectiveness that greatly depend on tillage type and soil texture.

2.2 Cover Crops

Legume or non-legume crops, as well as grasses, are sown as cover crops to improve soil health. Among the advantages of cover crops are enhanced soil health and increased agricultural sustainability. This review of the literature highlights the complicated and positive effects of conservation tillage and cover crops on soil health, nutrient dynamics, and crop yield. It does this by synthesizing the results of several studies on these topics. It emphasizes how cover crops reduce soil carbon loss, inhibit weed growth, and improve nutrient retention; however, these advantages come gradually, and in semi-arid areas, they can initially deplete soil water until but can be replenished with seasonal rains. The implementation of these methods is restricted by structural and economic obstacles, including initial expenses and gradual increases in soil quality, even though these practices may have long-term benefits for agriculture and the environment. All things considered, in order to overcome these obstacles and reach the full potential of conservation tillage and cover crops in sustainable agriculture, they need to be carefully managed and supported.

This paragraph summarizes a variety of research results regarding conservation tillage techniques and the implementation of cover crops, illustrating their nuanced effects on crop productivity. Without affecting crop yields, cover crops may improve a number of ecosystem services, according to Schipanski et al. (2014). Conservation techniques greatly lower production costs, however Jacobs et al. (2022) see uneven gains in soil characteristics and yields over a three-year period. According to Adetunji et al. (2020), cover crops are beneficial for releasing nutrients, increasing organic matter, and suppressing pests. Cover crops such as winter rye and other clovers have been shown to have neutral to negative effects on crop yields (Basche et al., 2016; Parr et al., 2011). Reese et al. (2014) and Acuna and Villamil (2014) note that cover crops have varying effects on corn and soybean yields in different environments. A potential production drop from cover crops can be minimized by employing mixed species, according to Abdalla et al. (2019), while Dozier et al. (2017) highlight the importance of cereal rye as an effective nitrogen scavenger without a short-term yield increase. According to Wittwer et al. (2017), the benefits of cover crops are greatest in organic systems with less tillage, demonstrating their function in maintaining yields under particular methods of agriculture. Together, these studies highlight the complex relationship between conservation tillage and cover crops in sustainable agriculture, highlighting both obstacles and chances to enhance agricultural productivity. The impacts of incorporating cover crops into traditional cropping systems are summarized in this paragraph, with varying conclusions regarding the health of the soil. In a three-year corn/soybean study comparing a conservation system to a conventional production system in Mississippi, Schipanski et al. (2014) examined soil characteristics, cash crop yield, and annual production costs. They emphasized that benefits from soil carbon accumulate gradually over decades, benefits from weed suppression carry over into the cash crop phase, and benefits from nutrient retention occur predominantly during cover crop growth. While Jacobs et al. (2022) indicate uneven gains in soil characteristics over a three-year period, they also note a noteworthy 86% decrease in soil loss when using no-till and cover crop strategies in contrast to conventional systems. According to Adetunji et al. (2020) and Koudahe et al. (2022), cover crops improve soil structure, promote nutrient release, and improve organic matter, all of which increase microbial activity and variety. But according to Reese et al. (2014), who investigated the effects of winter cover crops and landscape placements on corn (Zea mays L.) yield losses, high cover crop biomass decreased soil water availability, intensifying water stress and adversely affecting corn yield at Andover in 2011. All of these studies show the intricate relationships that exist between crop yield, soil management, and cover crops; they also indicate some of the difficulties and potential advantages that may arise. Burke et al. (2021) investigate how cover crops affect the dynamics of soil water in semi-arid areas. They discover that although cover crops absorb soil water that has been stored over the winter, this water is frequently supplied by spring rains and deficit irrigation prior to the planting of cotton. Their research casts doubt on the notion that in irrigated systems, winter cover crops reduce the amount of in-season soil water available, and instead suggests that implementing no-till after cover crop termination can enhance soil water availability for cotton development.

In the context of nutrient dynamics, Schipanski et al. (2014) describe how soil carbon accumulates gradually over decades, whereas cover crops improve nutrient retention during growth and control weeds through legacy effects. Nonetheless, variable fertilizer prices and prospective cost-sharing schemes impact economic feasibility. Basche et al.(2016) examined the effects of winter rye cover crops on crop productivity and environmental impacts in light of projected climate change using the Agricultural productivity Systems simulator (APSIM). They observed that although soil carbon sinks with time, cover crops greatly offset this loss by lowering nitrous oxide emissions, erosion, and other factors. According to Koudahe et al. (2022), under some circumstances, cover crops can increase soil organic carbon and nutrient availability. Although no additional effects on the soil were seen, Acuna and Villamil (2014) discovered that cover crops considerably reduce soil nitrate levels. Tillage increases soil organic matter but decreases soybean yields; cover crops enhance nitrogen scavenging without significantly altering other soil attributes after one production cycle, according to Dozier et al. (2017), who were attempting to evaluate the potential of cover crops to improve soil properties, retain nutrients in the field, and subsequently increase crop yields in Illinois. Blanco-Canqui (2018) notes that cover crops delay runoff, drastically cut sediment loss and runoff volume, and have varying effects on nutrient leaching. They are especially good at lowering nitrate leaching but less so with dissolved nutrients in runoff. Overall, even though cover crops have many positive effects on the environment, their complicated interactions with local conditions and soil management techniques make them worth carefully evaluating in terms of their effects on crop yields and economic results.

Jacobs et al. (2022) compared producers' present production systems with potential conservation systems in order to analyze the short-term implementation costs for them. They talk on the slow adoption rates of cover crops despite financial incentives, pointing out that upfront expenditures can be a major barrier and that measurable gains in soil quality from no-tillage and cover crops might take years to show. Focus group talks with farmers about how they get over obstacles and successfully use cover crops into their farming systems were conducted by Roesch-McNally et al. (2017). They describe how some farmers have effectively incorporated cover crops by using a comprehensive management strategy that involves making equipment and nutrient application adjustments. They highlight the value of farmer networks in resolving management issues and propose that lowering institutional obstacles can facilitate the adoption of these techniques to lessen the negative environmental effects of intensive agriculture. Overall, despite the fact that cover crops have a lot to offer in terms of improving soil health, structural, managerial, and economic obstacles prevent them from being widely adopted.

2.3 Enterprise Budgeting

Enterprise budgets are fundamental tools for agricultural decision-making, offering a detailed framework for analyzing financial aspects of farming operations. They guide farmers in evaluating profitability, managing risks, and optimizing production strategies in various market conditions. Through precise data integration and financial planning, these budgets are essential tools for effective farm management and economic resilience. Enterprise budgets estimate expenses and profits for a specific production period for a given activity, such as raising animals, producing grain, or cultivating vegetables. Each budget outlines the production system, the necessary inputs, the annual flow of activities, as well as a summary of the associated costs and returns. Most budgets are year-based. A budget will often contain income and expenses for a sample one-year period even for businesses whose production runs more than one year such as pecan or cow-calf operations (Doye and Sahs, 2016). Enterprise budgets are usually created by Land Grant Universities for a range of agricultural products that are typically grown in the state. These budgets are used in various forms and iterations for scholarly research and give farmers a tool for making business decisions that is specific to their financial operations. (Byrd, 2005; Dunn, 2008).

One of the fundamental pieces in constructing a whole-farm plan is an enterprise budget as farm managers can perform breakeven analysis, determine production costs, and choose between competing alternatives for production when they utilize enterprise budgets. (Dillon, 1983; Langemeier, 2015). Although, economic analyses on enterprise budgets for crops with niche markets where reliable data on price and yield data is difficult to obtain can lead to real world disappointments by giving farmers unrealistic predictions of profits (Awondo et. al, 2017).

For most crops, by organizing data into a framework that promotes more accurate decision making, the enterprise budget aims to control for inadequate knowledge regarding input and output involved in production (Fonsah and Rucker, 2003; Byrd, 2005). For instance, pricing forecasts aim to accurately forecast future returns based on past data, whereas experimental data obtained through test plots assigns a value to random variables such as yield per acre. Although the budget cannot change how random these variables are, it can help producers by giving a more thorough appraisal of the likelihood of future events. A successful budget's implementation depends on obtaining the most precise data possible for each input item. Consequently, the enterprise budget uses estimations of the combination of available inputs to deliver the best return/profits per acre (Byrd, 2005).

A successful enterprise budget does not only give insight into how profitable competing enterprises are or even how optimally should farmers produce a mix of products but in uncertain markets they can be utilized in forward contracting and hedging decisions as they can help producers determine whether a forward contract or hedge will return a profit or a loss depending on the price offer (LaPorte and McKendree, 2021).

2.4 Risk

Different producers perceive risky situations differently due to differences in their risk attitude. Three types of risk attitudes are distinguished: risk-averse, risk-neutral, and risk-seeking, each of which influences the utility function of the producer. The Expected Utility Theory (EUT), which was developed by Von Neumann and Morgenstern (1953), decision-makers seek to maximize expected utility amidst uncertainty. The utility function by Von Neumann-Morgenstern is U = U(w), where w represents wealth, illustrates this principle. While there are differences in the level of risk aversion, most research suggests that farmers are generally risk adverse. (Kahan, 2008; Menapace et al., 2013).

Arrow (1965) and Pratt (1964) further developed this concept by introducing measures of risk aversion—relative and absolute—used extensively to assess decision-making under uncertainty (Cochran et al., 1985; Babcock and Shogren, 1995; Simtowe, 2006; Campbell et al., 2021).

These measures assess a decision-maker's risk-taking propensity in relation to their amount of wealth and risk aversion. Using the following formulas, one can determine the relative risk aversion coefficient (rr) and the absolute risk aversion coefficient (ra) by taking the first (U') and second (U") derivatives of utility:

$$R_r = -\frac{U''(w)}{U'(w)}w \tag{1}$$

$$R_a = -\frac{U''(w)}{U'(w)} \tag{2}$$

By dividing by wealth, relative risk aversion can be converted to absolute, as shown by the following formula:

$$R_a(w) = \frac{R_r}{w} \tag{3}$$

Building on the theories of Arrow and Pratt, Anderson and Dillon (1992) found that the RRAC ranged from 0 to 4, signifying attitudes ranging from risk neutral to severely risk averse, respectively.

According to Richardson et. al., (2008), the minimal sum of money that a decision-maker would need in one lump payment to forsake a risky alternative is known as the "certainty equivalent," and the decision-maker is not concerned with the certainty equivalent or the predicted payout of the risky alternative in the future. The decision maker's expected utility function and degree of risk aversion determine the value of the certainty equivalent for each given risky alternative. One popular utility function that is used to depict a decision maker's utility function is the negative exponential utility function. The certainty equivalency formula using an exponential utility function is:

$$U(w) = -\exp(-r_a(w)w) \quad (4)$$

$$CE\big(w, ARAC(w)\big) = In\,\{(\frac{1}{n}\sum_i^n \exp(-ARAC(w)w)^{-1/ARAC(w)}\} \quad (5)$$

where,

CE = certainty equivalent

E(U) = expected utility

ARAC = absolute risk aversion coefficient

w = initial wealth

At different levels of risk aversion, the Certainty Equivalence can be investigated on the assumption that the expected utility function takes a particular form. The Absolute Risk Aversion Coefficient's value can be interpreted as

ARAC < 0, risk loving

ARAC = 0, risk indifferent

ARAC > 0, risk averse

An increase in the absolute value of the ARAC indicates a more risk-averse decision-maker.

2.5 Stochastic Efficiency with Respect to a Function (SERF)

Stochastic Efficiency with Respect to a Function (SERF), developed by Hardaker et al. (2004), ranks risky alternatives by calculating their certainty equivalents (CEs) for different levels of risk aversion, aiding decision-making under uncertainty (Liu et al., 2018; Williams et al., 2014). Richardson et al. (2008) further emphasize that SERF uses the Arrow-Pratt risk aversion coefficient alongside Expected Utility Theory (EUT) to quantify and compare the utilities of these uncertain outcomes, helping farmers understand the economic implications of their management choices under varying cost, price, and yield conditions. CEs are calculated for each outcome over a range of risk aversion coefficients (r) by using the inverse of the utility function using the following formula:

$$U(CE, r) = EU(w, r) = \sum_{i=1}^{m} U(w_i, r) P_{i,} \qquad (6)$$

$$r_1 \leq r \leq r_2$$

$$CE(w, r) = U^{-1}(w, r) \qquad (7)$$

Assessing the effects of agricultural methods like conservation tillage, cover crops, and irrigation management on farm economics has been done extensively using stochastic efficiency with respect to a function (SERF) (Adusumilli et al., 2020; Fan et al., 2020; Hignight et al., 2010; Watkins et al., 2010; Williams et al., 2012). SERF analysis helps determine the utility-weighted risk premium (RP) by comparing the certainty equivalents (CEs) of different practices at specific risk aversion levels.

RPs are calculated by subtracting the CE of their current choice (l) from the alternative choice (j) at a certain level of risk aversion (r):

$$RP_{j,l,r} = CE_{j,r} - CE_{l,r} \qquad (8)$$

Positive RPs suggest economic gains if producers switch to a more beneficial practice, indicating a higher likelihood of adoption. Conversely, negative RPs represent potential losses, with their absolute values indicating the cost producers would require accepting a riskier, less preferred practice.

2.6 Stoplight Chart

Stoplight Chart analysis is a visual analytical method designed to assist decision makers in evaluating the potential outcomes of various alternatives through color-coded probabilities. The Stoplight charts, created by Richardson and Outlaw (2008), provide a simple, intuitive method for assessing risk in decision-making by showing the likelihood of positive outcomes in green, negative outcomes in red, and intermediate possibilities in yellow. Overall, the Stoplight tool exemplifies how visual data representation can streamline and enhance decision-making processes, providing policymakers and industry leaders with a powerful means to navigate the complexities of risk and uncertainty in their respective fields.

This tool simplifies complex decision-making processes by visually communicating the risks associated with different policies without requiring detailed statistical or economic analysis or assumptions about the decision-maker's risk preferences. By providing a clear visual representation of risk, the Stoplight Chart enables policymakers to quickly grasp which course of action has the best chance of success and which is least likely to have negative effects (Richardson, Schumann, & Feldman, 2006).

The functionality of the Stoplight tool allows decision-makers to set specific upper and lower target outcomes for each policy scenario, integrating personal risk preferences into the evaluation process. This aspect is particularly useful as it customizes the analysis to reflect the specific risk tolerance levels of different stakeholders, making the tool adaptable to various decision-making contexts (Richardson et al., 2007).

The applicability of the Stoplight tool extends beyond policy analysis to include financial investments and agricultural management decisions, as demonstrated in studies by Evans and

Garcia (2016) and Vulchi et al. (2023). The tool has demonstrated its usefulness in optimizing farm management practices in agricultural contexts by being used to evaluate the risk profiles and economic viability of various tillage types, cropping sequences, and herbicide programs under both irrigated and rainfed environments.

Furthermore, the Stoplight Chart analysis eschews the need for intricate calculations or detailed economic models, making it an accessible option for decision-makers who may not have extensive backgrounds in economics or statistics. This accessibility is crucial for enabling informed, data-driven decision-making across a spectrum of policy areas and industries.

CHAPTER 3

DATA

3.1 Study Area

Data for this study was collected from a 6-year irrigated field experiment conducted at the University of Georgia's Southeast Research and Education Center (UGA SEREC) in Midville, Georgia. Midville is in Burke County and borders the Ogeechee River. The field used for the experiment was about 1.21 hectares in size, and the soil types found in this area are loam, loamy sand, and sandy loam.

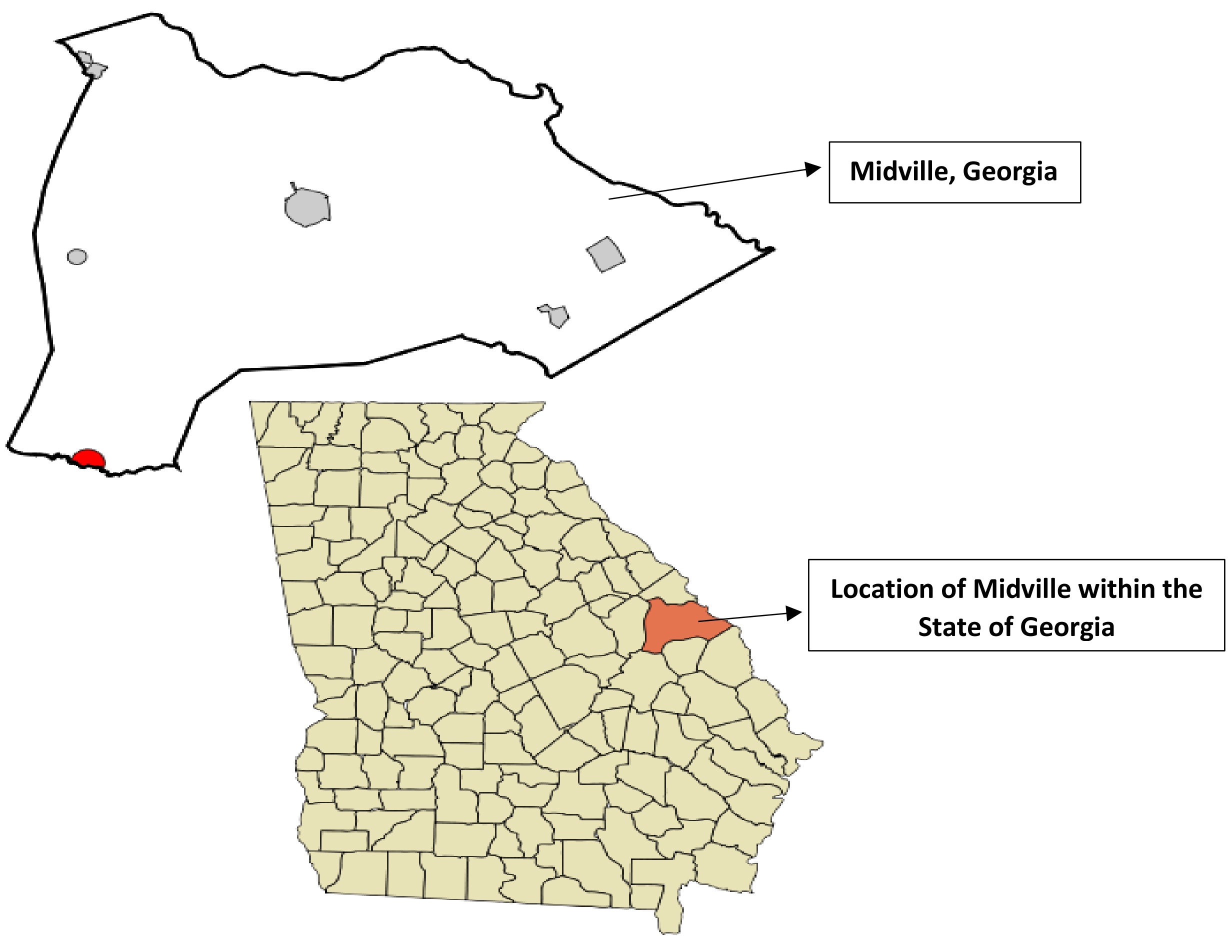


Figure 3.1. Geographic Representation of Midville in the State of Georgia.

3.2 Farm Experiment

For the experiment, the main crops were planted in rotation order of corn (Zea mays L.), peanut (Arachis hypogea L.), and cotton (Gossypium hirstum L.). This rotation was done 2 times over 6 years (2018-2023).

Table 3.1. Crop Rotation over the 6-year Study Period.

2018	**2019**	**2020**	**2021**	**2022**	**2023**
Corn	Peanut	Cotton	Corn	Peanut	Cotton

There were 16 treatment plots in total because this experiment employed a Randomized Complete Block Design (RCBD) with 4 treatments and 4 replications for each treatment. The four treatments include 1) Control of no cover crops with conventional tillage, 2) Cereal Rye under strip tillage, 3) Cereal Rye with ‘Dixie’ Crimson Clover under strip tillage and 4) a Mix of cover crops planted under strip tillage, respectively. The common cover crops utilized in Southeast Georgia served as the basis for the determination of these treatments. Which species were added to the Mix treatment depended on **the cash crop that** was **planted following the cover crop**, and this was determined based on the cover crop mix typically adopted by local growers for that specific cash crop (Tostensen, 2023). 'AU Robin' red **clover, 'Cosaque' black-seeded oats (Avena sativa L.), tillage/cultivated radish (Raphanus sativus L.), 'Cahaba' white vetch (Vicia sativa L.), and 'Bayou' forage kale (Brassica oleracea var. sabellica L**.) were the five species mix planted in the 2018 season (Tostensen, 2023). A "Bayou" forage kale blend, "Cahaba" **white vetch, "Shield" yellow mustard (Brassica hirta Moench or Sinapis alba L**.), "Cosaque" black-seeded oats, tillage/cultivated radish, and "Dixie" red clover (Trifolium incarnatum L.) were planted in 2019, 2020, and 2021 (Tostensen, 2023). The following were planted in 2022, including 42 "**Dwarf Essex" rapeseed (Brassica napus L**.), "AU Sunrise" red **clover (Trifolium incarnatum L.), "Cahaba" white vetch, tillage/cultivated radish**, and "Bayou" forage kale mixture. A blend of "Bayou" forage kale, "Cahaba" white vetch, "Dixie" red **clover, Persian clover (Trifolium resupinatum L**.), "Gulf" annual ryegrass **(Lolium multiflorum Lam.), and** "Cosaque" black-seeded oats were planted in 2023 (Tostensen, 2023).

A Great Plains three-point hitch lift interval seed drill was used to plant the cover crop treatments in each of the study's years. Although the drill spacing is 19 cm for rows out of the box, every other drill cup was blocked to plant the cover at 38 cm (about 1.25 ft). This was done to make a 38-cm furrow that would accommodate the planter and strip-till equipment. The plots were 122 meters (about 400.26 ft) long and 12 rows broad at 91 cm (about 2.99 ft) intervals. **The seeding rates for each year are** shown in Table 3.2.

Table 3.2 **Cover Crop Seeding Mixtures and Rates for 2018 through 2023 Seasons**

	Treatment (seed rate lbs/acre)		
	Cereal Rye	Rye & 'Dixie' Crimson Clover	'AU Robin' **Crimson Clover, 'Cosaque' Oats, Tillage Radish, 'Cahaba' Vetch & 'Bayou'** Kale
2018	78.4	67.3 + 11.2	5.6 + 39.2 + 1.12 + 3.36 + 1.12
			'Dixie' Crimson Clover, 'Cosaque' Oats, Tillage Radish, 'Cahaba' Vetch, Yellow Mustard & 'Bayou' Kale
2019	78.4	67.3 + 11.2	5.6 + 39.2 + 1.12 + 3.36 + 1.12
2020	78.4	67.3 + 11.2	5.6 + 39.2 + 1.12 + 3.36 + 1.12
2021	78.4	67.3 + 11.2	5.6 + 39.2 + 1.12 + 3.36 + 1.12
			'Cosaque' Oats, 'AU Sunrise' Crimson Clover, 'Cahaba' Vetch, Tillage Radish, 'Dwarf Essex' Rapseed & 'Bayou' Kale
2022	78.4	67.3 + 11.2	**39.2 + 5.6 + 2.24 + 1.12 + 1.12 + 1.12**
			'Cosaque' Oats, 'Gulf' Annual Ryegrass, 'Dixie' Crimson Clover, Persian Clover, 'Cahaba' Vetch & 'Bayou' Kale
2023	78.4	67.3 + 11.2	**33.6 + 5.60 + 3.36 + 2.24 + 1.12 + 1.12**

Source: Tostensen (2023)

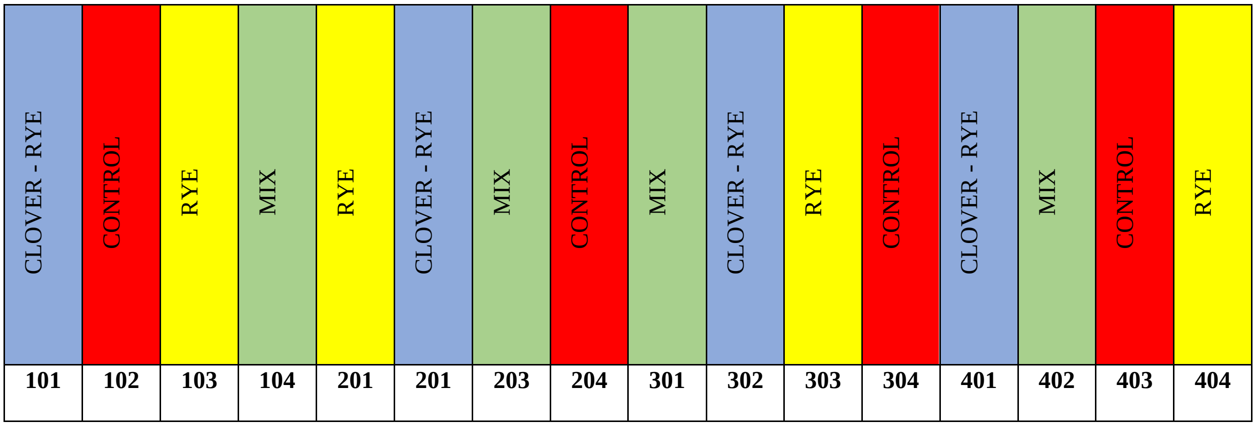


Figure 3.2. **Plot design for** the **cover crop study in Midville**, Georgia.

In order **to determine the potential** impact of **cover crop treatments on** agricultural production systems in the Coastal Plain, samples of **soil and biomass were collected**. Before 2022, UGA Extension staffers collected soil and biomass samples using specific sampling techniques. For the 2022 season, a more thorough **adaptation of the UGA Extension's handbook**'s suggested approach for collecting soil and biomass samples, bias and error in data collection were reduced and experiment results were more accurate overall. A condensed version of the key dates for each growing season is provided in Table 3.3 below.

Table 3.3. Essential Dates Compiled into a Single, Simply Legible Table for Every Growing Season.

Year	**Main Crop**	**Cover Crop Planting Date**	**Cover Crop Sampling Date**	**Termination Date for Cover Crop**	**Main Crop Planting Date**	**Pre-harvest Preparation Date**	**Main Crop Harvesting Date**
2018	Corn	**10/26/17**	**4/10/18**	**4/12/18**	**4/11/18**		**8/24/18**
2019	Peanut	**10/19/18**	**4/8/19**	**4/11/19**	**5/10/19**	**10/5/19**	**10/10/19**
2020	Cotton	**10/25/19**	4/15/20	4/15/20	**5/22/20**	**10/2/20**	**10/23/20**
2021	Corn	**11/9/20**	**3/22/21**	**3/24/21**	**4/9/21**		**9/7/21**
2022	Peanut	**10/26/21**	**3/26/22**	**4/15/22**	**5/17/22**	**10/24/22**	**11/2/22**
2023	Cotton	**11/10/22**	4/8/23	4/24/23	5/17/23	10/5/23	11/7/23

Source: Tostensen(2023)

Note: The date peanuts were dug, or cotton was defoliated was known as the "pre-harvest prep date." There was no pre-harvest prep for corn.

3.3 Cash Crop Management

To prepare the land for sowing **the cash crop, a four-row Kelley Manufacturing Company strip-till** machine **was pulled by a 180** horsepower tractor. When the furrow was being constructed, the strip-till tool's wide rollers helped **roll or push the cover crop down** (Tostensen, 2023)**. The** cash crop seed was put in this furrow. **A four-row hydraulic drive John Deere 7300 Max Emerge planter** was used to plant all the crops in this study. Corn variety Cropland (**CG) 5678 (WinField United, Arden Hills, MN) was planted** between 2018 and 2021. 2020 and 2023 saw the planting of "Deltapine (DP) 1646" (Bayer Crop **Sciences) cotton**, and 2019 and 2022 saw the sowing of "Georgia-06G" peanuts. While "Georgia-06G" peanuts were sowed in 2019 and 2022, cotton "Deltapine (DP) 1646" **(Bayer Crop Sciences) was planted** in 2020 and 2023 (Tostensen, 2023). The field was irrigated using two tower overhead pivots and an electric pump. Irrigation was scheduled using the **UGA Checkbook Method (UGA Extension, 2022). The** research station staff decided and carried out the irrigation and nutrient management.

Data on yield were gathered from the four center rows of every plot after the growing season. A Case IH 1640 four-row combine was used to harvest corn. Cotton **was harvested** with **a John Deere 9965 four-row picker, and peanuts were harvested using a KMC 3350 four-row combine**. According to Tostensen (2023), field weight at harvest was used to calculate peanut yield. The collected **seed cotton yield was used to** calculate the ultimate yield for each cotton plot, as the cotton production from each plot was thereafter **sent to the gin to determine** the **turnout** for the ultimate lint yield (**Raper et al., 2000). Corn**'s moisture content was changed to 15.5%, the industry **standard (Mulvaney and** Devkota, 2020). Additionally, peanuts' moisture content was maintained at 10.5%, which is **the University of Florida's standard moisture** percentage (Mulvaney and Devkota, 2020). The main crop varieties and sowing rates utilized in the study are presented in Table 3.4.

Table 3.4. Variety and Seeding Rate for Main Crops Each Year.

Crop	**Year**	**Variety**	**Seeding Rate**
Corn	2018	CG 5678	34,000 seeds per acre
Peanut	2019	GA-06G	20 seeds per meter
Cotton	2020	DP 1646	36,300 seeds per acre
Corn	2021	CG 5678	34,000 seeds per acre
Peanut	2022	GA-06G	20 seeds per meter
Cotton	2023	DP 1646	37,000 seeds per acre

3.4 Net Return

We used input usage and yield data from the field experiment for each of the four treatments to assess the economic benefits of implementing strip-till and cover crops in irrigated corn, peanut, and cotton production. For each treatment i (where i = Control, Rye only, Rye and Crimson Clover only, and Mix) during production season or year t (where t = 2018,…..,2023), peanut and corn yields were obtained from weighing field harvest and drying them to meet the required moisture content. After seed cotton was ginned, the field experiment yielded lint per hectare for cotton. The nominal gross revenue of each main crop was calculated using their yields for each year and the historical prices of those crops in those production years.

$$\text{Corn gross revenue}_{i,t} = \ corn\ price\ \times\ corn\ yield_{i,t} \quad (1)$$

$$\text{Peanut gross revenue}_{i,t} = \ peanut\ price_{i,t}\ \times\ peanut\ yield_{i,t} \quad (2)$$

$$\text{Cotton gross revenue}_{i,t} = \ cotton\ lint\ price_{i,t}\ \times\ cotton\ lint\ yield_{i,t} \quad (3)$$

Prices for Georgia's corn, peanuts, and cotton lint from 2018 to 2023 were obtained from the National Agricultural Statistics Service (USDA-NASS, 2023) of the United States Department of Agriculture. The Consumer Price Index (CPI) was used to convert nominal gross revenue to real gross revenue in USD in 2023 (Bureau of Labor Statistics, 2023):

$$Real\ gross\ revenue_{i,t} = \frac{CPI_{2023}}{CPI_t} \times nominal\ gross\ revenue_{i,t} \tag{4}$$

For each production year, the total cost of production was calculated as the total of input cost and cost of management practices. These costs were accurately estimated using enterprise budgets which were developed by the University of Georgia's Agricultural Economics and Extension Department (University of Georgia, 2023). Since the reference year for analysis is 2023, the production costs for each year were determined using the irrigated corn, peanut, and cotton enterprise budgets for 2023. Two types of cost analysis were done; an enterprise budget analysis to ascertain how the cost structure of each treatment differs from each other and which cost components drive these differences and also an incremental cost analysis in order to successfully run a Stochastic Efficiency with Respect to a Function (SERF) analysis, since SERF requires that the average net return is positive in order to satisfy risk aversion parameters.

The total cost per hectare for the enterprise budget study includes the variable and fixed expenses for strip tillage and the planting, cultivation, and harvesting of corn, peanuts, and cotton under the four distinct cover crop treatments. For incremental cost analysis, the expenses of planting and terminating cover crops, as well as planting, growing, and harvesting the primary cash crops, were the same for every cover crop plot each year, except for variances in cover crop seed costs and tillage costs. Hence, only cover crop seed cost and tillage cost made up the total cost under the incremental cost analysis.

Consequently, the variable expenses for the enterprise budget analysis included labor, fuel, custom chemical application, maintenance, fertilizer, operating interest, chemicals (such as growth regulators, herbicides, fungicides, and insecticides), and harvest costs. Depreciation, interest on equipment (such as tractors, planters, sprayers, trucks, harvesters, etc.), insurance, and land rental comprised the fixed costs. The total cost under enterprise budget and incremental cost analysis was calculated using the following equations respectively:

$$\text{Total cost}_{i,t} = \mathit{input\ cost}_{i,t} + \mathit{fuel\ and\ repair\ cost}_{i,t} + \mathit{custom\ applications}_{i,t} + \mathit{depreciation}_{i,t} + \mathit{interest}_{i,t} + \mathit{harvest\ cost}_{i,t} \quad (5)$$

$$\text{Total cost}_{i,t} = \mathit{cover\ crop\ seed\ cost}_{i,t} + \mathit{tillage\ cost}_{i,t} \quad (6)$$

For every production season and for each of the four cover crop treatments, the net return per hectare for each main crop's production was computed as follows:

$$\text{Net return}_{i,t} = \mathit{Real\ gross\ revenue}_{i,t} - \mathit{Total\ cost}_{i,t} \quad (7)$$

The R program was used to analyze variance (ANOVA) to compare the differences in the major crop yield mean values between the tillage and cover crop treatments. Pairwise comparisons were performed using Tukey's Honestly Significant Difference Test at the 95% confidence interval (P value < 0.05).

CHAPTER 4

METHODOLOGY

4.1 Stoplight Chart Analysis

A Stoplight Chart Analysis helps clarify the distribution of net returns. The likelihood that risky alternatives will produce values below a lower target value, above an upper target value, and in between the set values is determined by the Stoplight Chart Analysis (Richardson et al., 2008). The 25th percentile for the lower bound and the 75th percentile for the upper bound is the most widely used definitions of bounds. Boundaries were established using net return values from each treatment under a specific main crop.

4.2 Stochastic Efficiency with Respect to a Function (SERF)

The use of cover crops and strip tillage, as opposed to conventional tillage without a cover crop, may help stabilize crop productivity by improving the soil's ability to hold water, adding more organic carbon and nitrogen, increasing soil worm activity, and reducing soil erosion (Fan et al., 2020). But adopting cover crops, however, comes with additional costs for cover crop seed, planting, and harvesting, but strip tillage reduces expenses on the tillage process as opposed to conventional tillage. Producers may experience higher income volatility due to rising costs and revenues combined. Hence, producers' levels of risk aversion determine the combination of tillage and cover crop production strategies they may prefer (Ribera et al., 2004; Fan et. al 2020).

Less income risk is preferred by risk-averse decision-makers for the same amount of expected return. Taking this into consideration, we incorporated the producers' risk-taking behaviors and the uncertainty in the framework for making decisions (Richardson et al., 2000). Furthermore, risk-averse farmers are more inclined to employ farming practices that produce stable farm income. Net return per hectare distributions for strip-till with cover crop treatments and conventional tillage without cover crops were ranked using stochastic efficiency with respect to a function (SERF). The SERF process has been extensively utilized to assess a range of risky options and calculate risk premiums to facilitate decision-making (Liu et al., 2018; Williams et al., 2014; Fan et al., 2020).

For a range of risk aversion levels, SERF ranks a set of risky choices according to certainty equivalents (Hardaker et al., 2004). Under price, costs, and yield uncertainty, the SERF method can help producers understand their choices given their perceived risk preferences. According to Fan et al., (2020), The guaranteed sum of money that a decision-maker would be ready to pay in lieu of a risky alternative is known as the CE of that alternative.

According to Varian (1992), the calculation of CE for a given utility function is as follows:

$$CE\,[w, r(w)] = U^{-1}\,[w, r(w)] \tag{8}$$

The decision-maker's utility function with a risky alternative, w (wealth), is represented as U(w). The Arrow–Pratt measure of absolute risk aversion coefficient (ARAC) is defined by Arrow (1965) and Pratt (1964) as:

$$ARAC = -\frac{U''(w)}{U'(w)} \tag{9}$$

Together with the definition of the relative risk aversion coefficient (RRAC), which is:

$$RRAC = -w\frac{U''(w)}{U'(w)} \tag{10}$$

where w is the wealth or outcome for a risky alternative, U is a Bernoulli utility function that can be differentiated twice, U'' is the second derivative of the utility function, while U' is its first derivative. A risk-averse individual prefers to choose risky options with a higher certainty equivalent over those with a lower certainty equivalent. In other words, a decision-maker will select the risky option that yields the highest certainty equivalents (Williams et al., 2014; Watkins et al., 2018; Fan et al., 2020).

According to Hardaker et al., (2004) and from equation 8, It is necessary to provide a utility function to compute the certainty equivalent. A negative exponential utility function was used in our study. According to Hardaker et al., (2004), the negative exponential utility's functional form is expressed as:

$$U(w_i) = -\exp(-r_a(w)w_i) \tag{11}$$

where w_i is a risky outcome and r_a is the Arrow-Pratt absolute risk-aversion coefficient. According to Hardaker et al. (2004), the estimated certainty equivalent for an exponential utility function is expressed as:

$$CE\left(w_i, r_a(w)\right) = In\,\{(\frac{1}{n}\sum_i^n \exp(-r_a(w)w_i)^{-1/r_a(w)}\} \tag{12}$$

for a random sample of size n and a risky alternative with outcome w_i, with a particular r_a. The decision-maker is assumed to be risk-averse and to have constant absolute risk aversion by the negative exponential utility (Babcock, Choi, & Feinerman, 1993; Williams et al., 2012). Relative risk aversion coefficient (RRAC) can be converted to ARAC in accordance with this information (Raskin and Cochran, 1986). RRAC(w) = 0 for risk neutral, RRAC(w) = 1 for somewhat risk-averse, RRAC(w) = 2 for quite risk-averse, RRAC(w) = 3 for very risk-averse, and RRAC(w) = 4 for extremely risk-averse are the relative risk aversion levels employed in this study (Anderson

& Dillon, 1992; Fan et al., 2020). The following formula was used to get the upper bound of the absolute risk-aversion coefficient (Hardaker et al., 2004):

$$ARAC(w) = \frac{RRAC(w)}{w} \tag{13}$$

where the average net return of each main crop's production over all cover crop and tillage treatments was used to estimate w. Given a specific degree of risk aversion, the utility weighted risk premium (RP) for strip-till with cover crops relative to conventional tillage without a cover crop can be calculated as follows (Fan et al., 2020):

$$RP_{ST,CT,r_a(w)} = CE_{ST,r_a(w)} - CE_{CT,r_a(w)} \tag{14}$$

The minimum compensation per hectare for a given level of risk aversion that a decision-maker must obtain in order to transition from a favored activity to a less desirable one is represented by the value of Risk Premium (Hardaker et al., 2015; Mwinuka et al., 2017). A positive risk premium indicates that the producer favors strip-till with cover crops over conventional tillage without cover crops. The predicted benefit of implementing strip-till with cover crops can also be interpreted as a positive risk premium value (Fan et al., 2020). Conversely, a negative risk premium indicates that the producer would rather use conventional tillage over no-till with or without cover crops. The expected loss or compensation that producers would require to switch to strip-till with cover crops might be interpreted as the negative value of risk premium. Using Simulation and Econometrics to Analyze Risk (SIMETAR), the SERF research was conducted. For irrigated corn, peanuts, and cotton production, the SERF analysis was done using strip tillage with various combinations of cover crops.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Corn Results

Corn Yield

From Table 5.1, conventional tillage with no cover crops (control) had the highest average yield of 14280.4kg/ha followed by the Mix treatment with 13766.81kg/ha. The control treatment also had the least standard deviation showing that its yields are the least volatile among all treatments but although the Mix treatment provides higher yields on average, its standard deviation is fairly high showing that yields might vary significantly in between years. The Rye and Crimson Clover treatment has the largest range and the highest standard deviation which shows that yields are most volatile under this treatment. The ANOVA results show that yields across treatments are not statistically different.

Table 5.1 Summary Statistics of Corn Yield Under the Different Treatments.

	Corn yield (kg/ha)					
	Minimum	**Maximum**	**Mean**	**Standard Deviation**	**CV**	**ANOVA F – Statistic (P value)**
Control	11717.81	16703.72	14280.40	1508.66	10.56	0.726 (NS)
Rye	11028.37	14763.92	13037.26	1238.53	9.50	(0.545)
Rye and Clover	7208.36	17541.09	12966.56	2856.37	22.03	
Mix	9567.56	16933.09	13766.81	2312.55	16.80	

Note: "NS" means Not Statistically Significant, and "CV" means Coefficient of Variation

Corn Production Cost

As depicted by Figure 5.1, the Mix treatment has the highest cost of production with a total of $1,589.62 followed by the control, Rye and Crimson Clover only, and Rye only treatments with $1582.83, $1,577.5, and $1,564.87, respectively. It can be noticed that since almost all management practices were the same across all treatments, the major differences in cost were driven by differences in treatment costs (cover crop and tillage costs) among treatments with cover crops. Hence, as far as treatment costs are concerned, treatments with cover crops had a higher cost of production but the high cost associated with the control treatment was due to drying, harvesting, and conveying cost associated with higher yields. Also, the more cover crop species employed in a treatment, the more likely treatment costs and total production costs are going to increase.

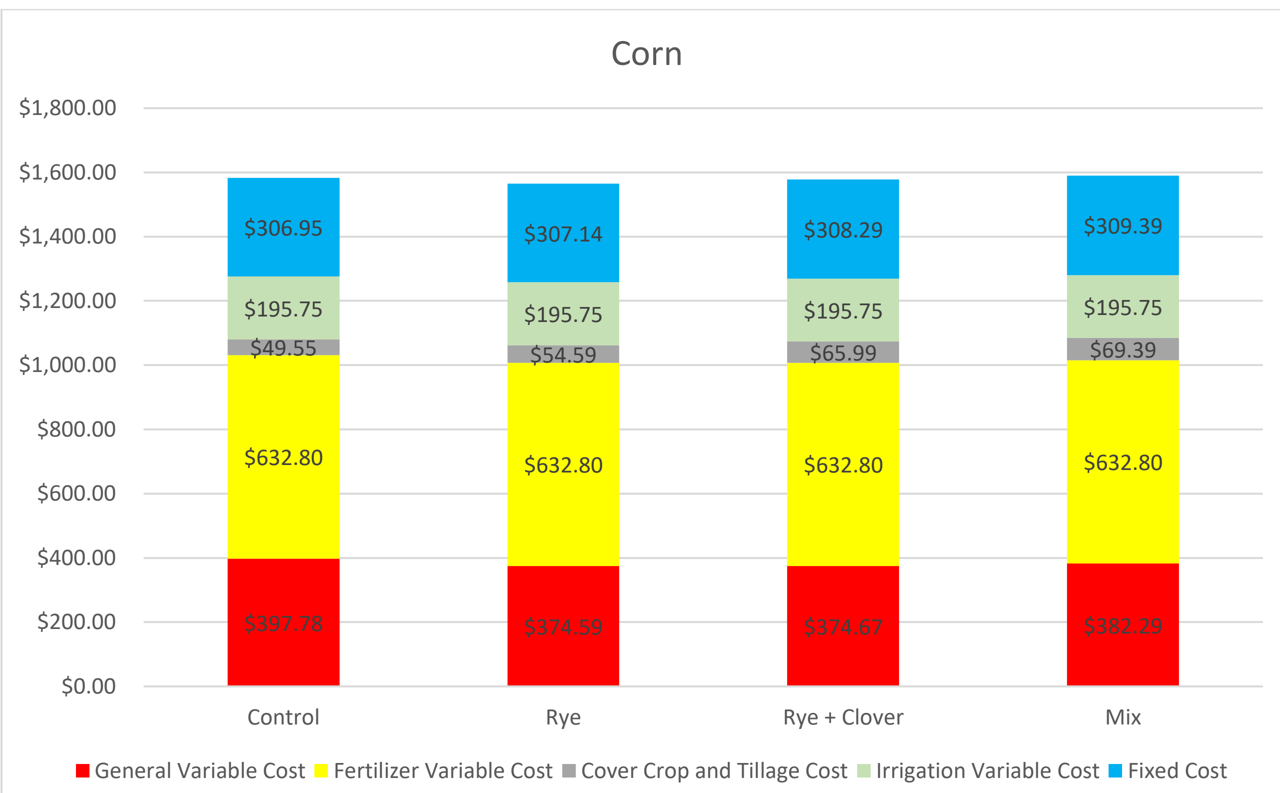
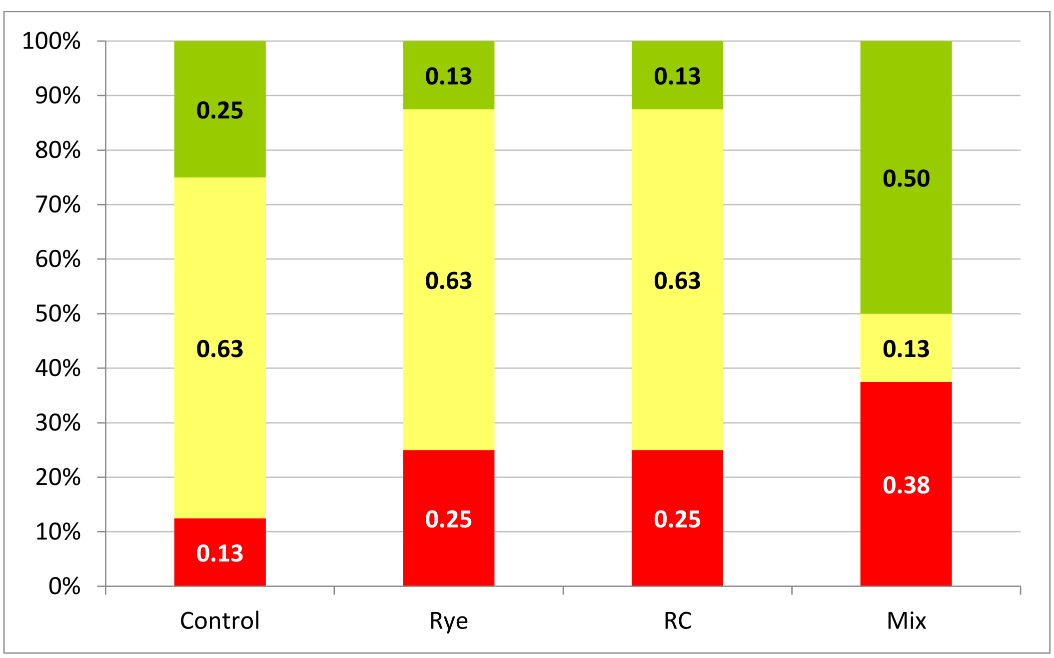


Figure 5.1 Corn Production Costs Across all Treatments

Distribution of Corn Net Returns

The reference net returns for the stoplight chart analysis of corn were $2,049.49 (25th Percentile) and $3,225.03 (75th Percentile). From figure 5.2, Rye only and Rye and Crimson Clover only have the same distribution of net returns. They both have 13% probability of generating net returns greater than the upper value and a 25 % chance of generating a net return less than the lower value but a 63% probability of generating a net return between the upper and lower value. The Mix treatment has the highest probability of giving a producer a favorable return (50% probability of generating a net return greater than the upper value) but it also has the highest probability of generating an unfavorable net return (38% probability of generating a net return less than the lower value). The control treatment on the other hand has 25% probability of generating a favorable net return but has the least probability of generating an unfavorable net return (13%). Risk averse producers will favor the control treatments as it provides less risk in terms of the probability of obtaining a favorable net return.



Note: “RC” means Rye and Crimson Clover treatment

Figure 5.2. Stoplight Chart of Corn Net Returns

Stochastic Efficiency with Respect to a Function (SERF)

Certainty Equivalent

The downward trend of the curves in Figure 5.3 show that as ARAC or risk aversion increases, certainty equivalent across all treatments tend to also decrease. Note that the certainty equivalent for the control treatment is the highest across all risk aversion levels, ranging from $2,729.33 to $2503.34. This means the control treatment is the most preferred treatment by producers while Rye and Crimson Clover only treatment is the least preferred treatment by producers as it has the lowest certainty equivalents across all levels of risk aversion. The certainty equivalent of Rye only ranges from $2,577.11 to $2,294.95 while that of the Mix treatment ranges from $2,699.49 to $2,258.09. Between those two treatments, risk neutral to very risk averse producers prefer the mix treatment to the Rye only treatment but extremely risk adverse producers prefer the Rye only treatment to the Mix treatment.

Risk Premium

From figure 5.4, it is noticed that across all treatments, as producers become more risk averse they prefer to practice conventional tillage without cover crops than strip tillage with cover crops. For a risk neutral producer (ARAC = 0.00), shifting from the control to a treatment with cover crops earns them a loss of at least $29.85 per hectare for Mix treatment and at most $206.14 per hectare for the Rye and Crimson Clover only treatment. At the highest level of risk aversion (ARAC = 0.0015), shifting from the control to a treatment with cover crops earns them a loss of at least $208.38 per hectare for the Rye only treatment and at most $427.54 per hectare for the Rye and Crimson Clover only treatment.

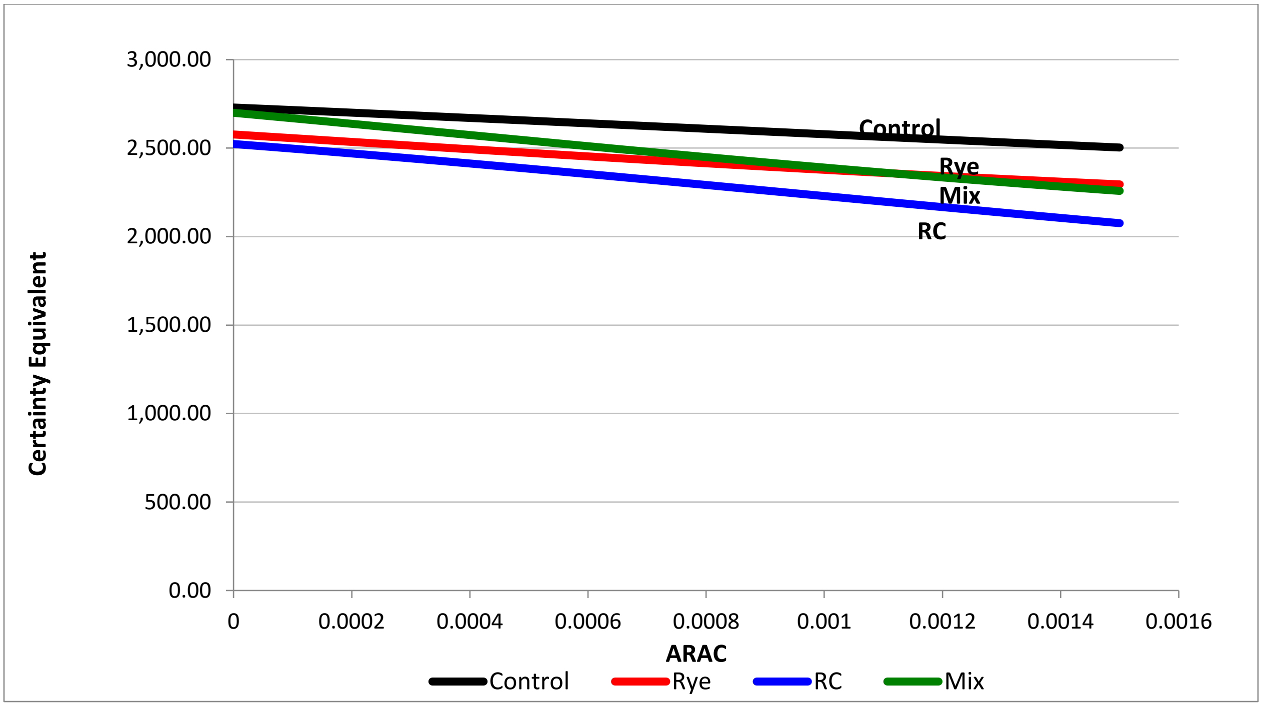


Figure 5.3. Stochastic Efficiency with Respect to a Function under Negative Exponential Utility for Corn Production

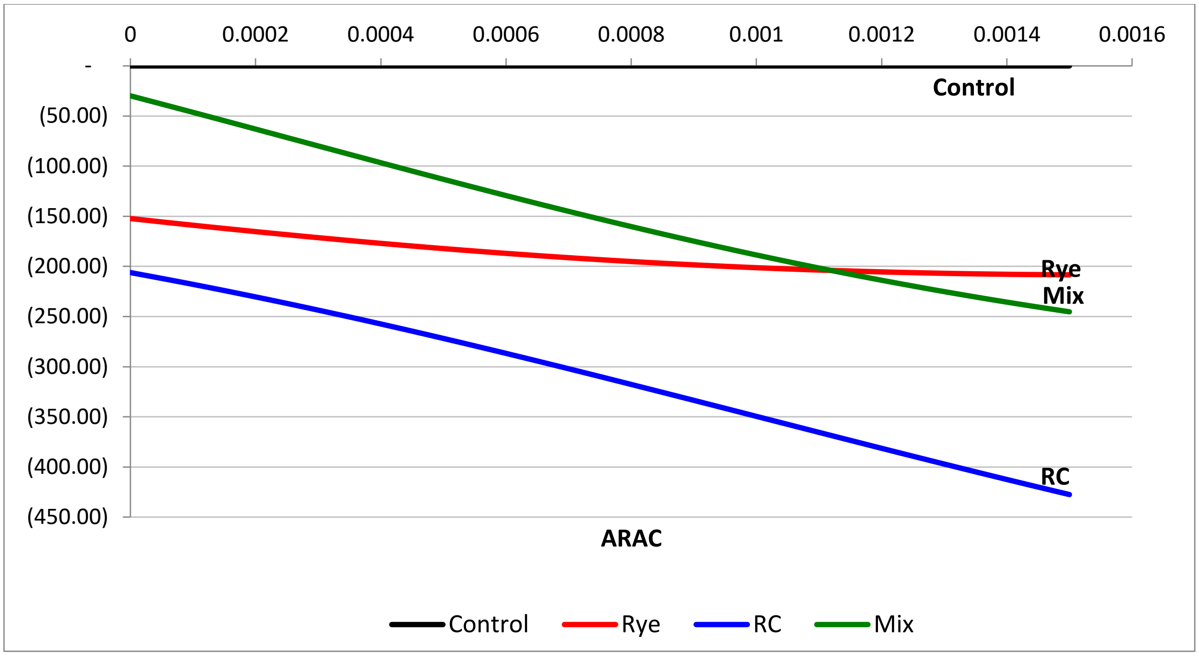


Figure 5.4. Negative Exponential Utility Weighted Risk Premiums Relative to Net Returns per Hectare for Corn Production

Table 5.2 Utility Weighted Risk Premiums for Cover Crop Treatments Relative to Control under Corn Production.

	Risk Neutral	*Somewhat Risk Averse*	*Rather Risk Averse*	*Very Risk Averse*	*Extremely Risk Averse*
	0.00	0.0004	0.0008	0.0011	0.0015
Risk Premiums for Control ($/ha)					
Rye Only	*($152.22)*	*($175.59)*	*($193.25)*	*($202.77)*	*($208.38)*
Rye and Crimson Clover	*($206.14)*	*($253.89)*	*($309.84)*	*($359.53)*	*($427.54)*
Mix	*($29.85)*	*($92.39)*	*($152.73)*	*($196.81)*	*($245.25)*

5.2 Peanut Results

Peanut Yield

From Table 5.3, the control had the highest average yield of 8055.32kg/ha followed by the Mix treatment with 7673.62kg/ha. Unlike for corn, the Mix treatment had the least standard deviation showing that its yields are the least volatile among all treatments. Although the control treatment provides higher yields on average, its standard deviation is the highest showing that yields might vary significantly in between years. The Rye only treatment has the largest range and the second highest standard deviation which shows that yields are also very volatile under this treatment. The ANOVA results show that yields across treatments are statistically different at a significant level of 5% with the significant difference found between yields of control and that of Rye and Crimson Clover only treatment.

Table 5.3 Summary Statistics of Peanut Yield Under the Different Treatments.

	Peanut (kg/ha)					
	Minimum	**Maximum**	**Mean**	**Standard Deviation**	**CV**	**ANOVA F – Statistic (P value)**
Control	7290.42 a	9326.72	8055.32	745.34	9.25	3.375**
Rye	6217.74 ab	8476.71	7183.11	745.02	10.37	(0.032)
RC	6184.55 b	7911.95	7096.42	646.67	9.11	
Mix	7012.54 ab	8651.94	7673.62	610.75	7.96	

Peanut Production Cost

As depicted by Figure 5.5, the Control treatment has the highest cost of production with a total of $1,388.11 followed by the Mix, Rye and Crimson Clover only, and Rye only treatments with $1,337.94, $1,325.62, and $1,314.40, respectively. It can also be noticed that since almost all management practices were the same across all treatments, the major differences in cost were driven by difference in treatment costs (cover crop and tillage costs) among treatments with cover crops. Unlike the results for corn, treatments with cover crops had a lower cost of production as the high cost associated with the control treatment was due to drying, harvesting, and conveying cost associated with higher yields. Also, the more cover crop species employed in a treatment, the more likely treatment costs and total production costs are going to increase.

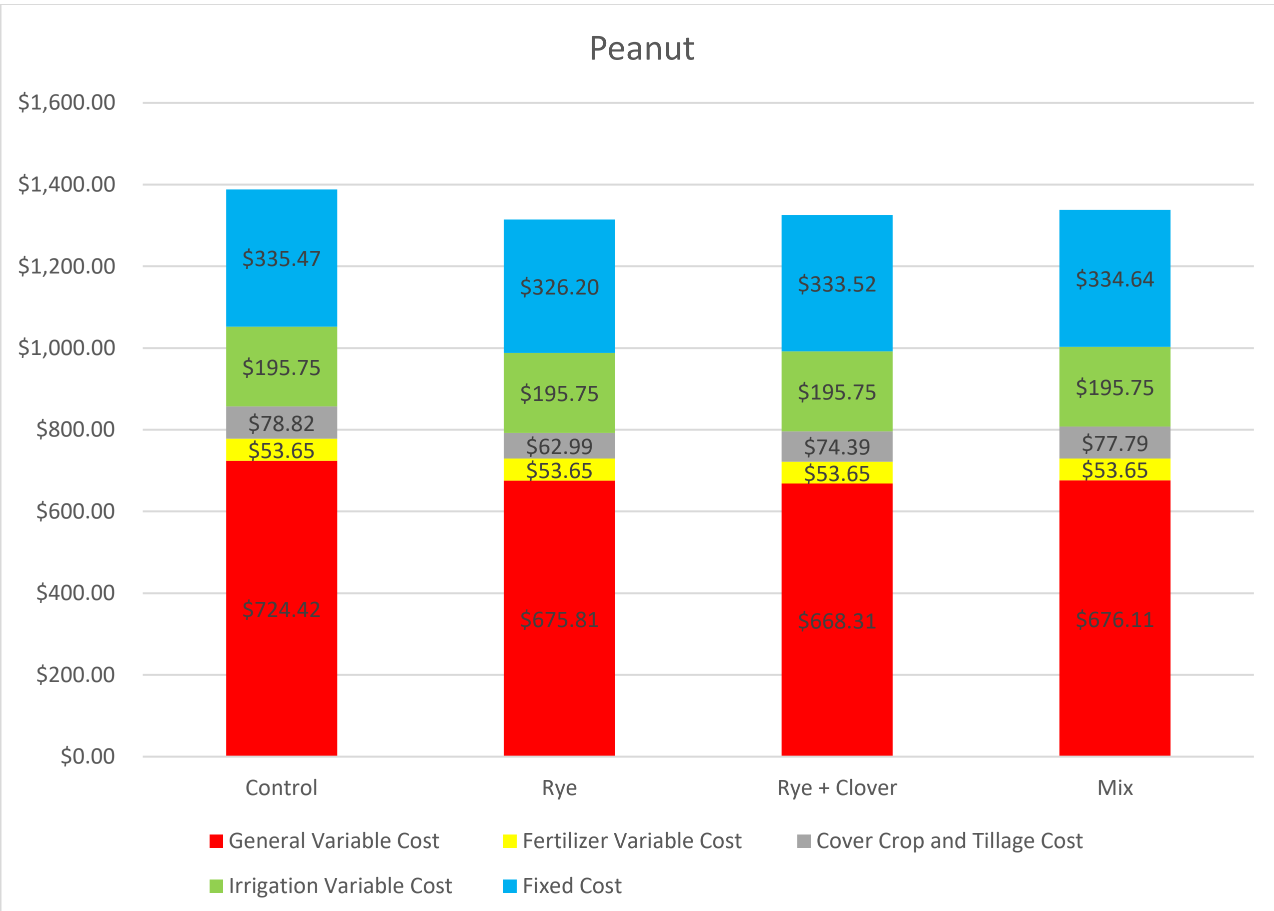


Figure 5.5 Peanut Production Costs Across all Treatments

Distribution of Peanut Net Returns

The reference net returns for the stoplight chart analysis of peanut were \$3,895.40 (25^{th} Percentile) and \$4,180.95 (75^{th} Percentile). From figure 5.6, Rye only and Rye and Crimson Clover only have the most unfavorable distribution of net returns. They both have the two highest probabilities of generating net returns less than the lower value (that is 63% probability for Rye only and 50% probability for Rye and Crimson Clover only treatment). They also have the least probabilities among all treatments to obtain a net return higher than the upper value with Rye and Crimson Clover only treatment having no chance at all. The Control treatment has the highest probability of giving a producer a favorable return (63% probability of generating a net return greater than the upper value) followed by the Mix treatment with a 25% probability. Both these treatments have no chance of generating an unfavorable net return (0% probability of generating a net return less than the lower value). Risk averse producers will favor the control treatments as it provides less risk in terms of the probability of obtaining a favorable net return and a higher chance for even more favorable net returns.

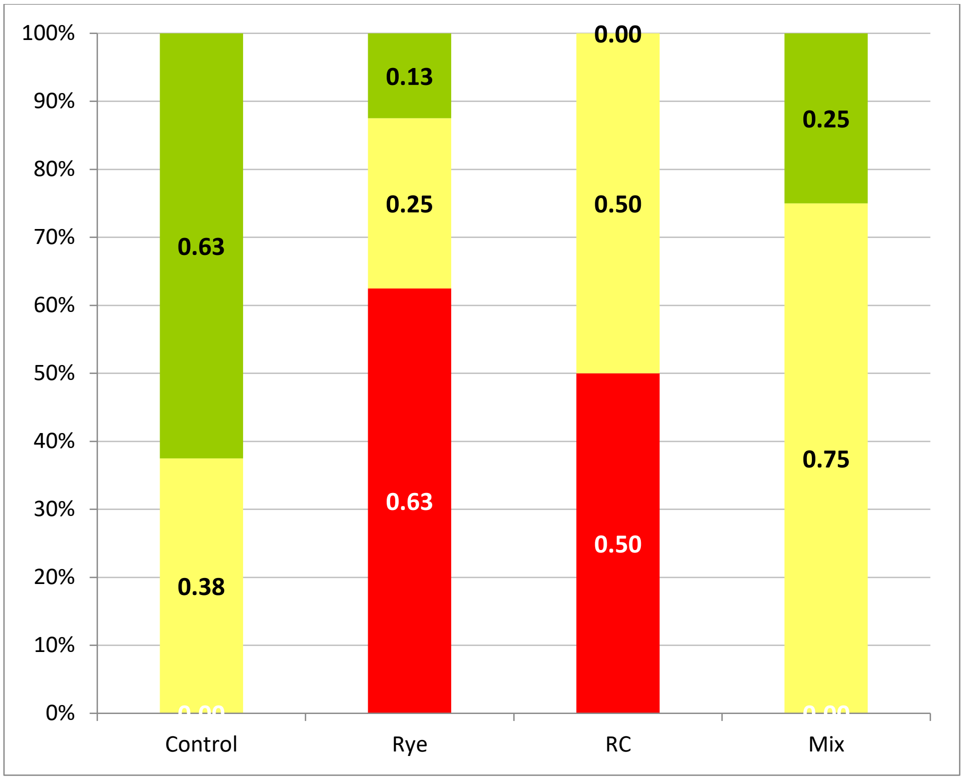


Figure 5.6. Stoplight Chart of Peanut Net Returns

Stochastic Efficiency with Respect to a Function (SERF)

Certainty Equivalent

The downward trend of the curves in Figure 5.7 shows that just like corn, as ARAC or risk aversion increases, certainty equivalent across all treatments tend to also decrease. It can be noticed that the certainty equivalent for the control treatment is the highest across all risk aversion levels, ranging from $4,245.5 to $4,279.59. This means the control treatment is the most preferred treatment by producers while Rye and Crimson Clover only treatment is the least preferred treatment by producers as it has the lowest certainty equivalents across all levels of risk aversion. The certainty equivalent of Rye only ranges from $3,914.38 to $3,944.91 while that of the Mix treatment ranges from $4,169.8 to $4,188.24. Between those two treatments, across all levels of risk aversion the Mix treatment is preferred to all other cover crop treatments.

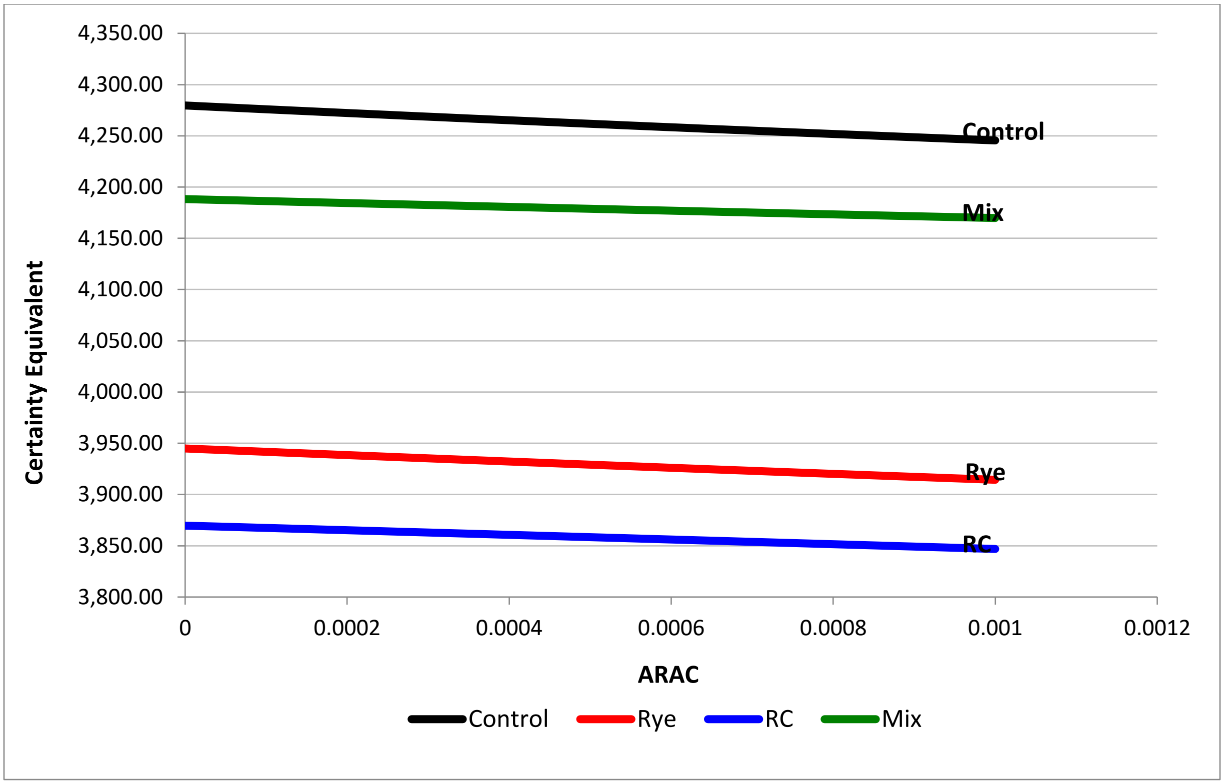


Figure 5.7. Stochastic Efficiency with Respect to a Function under Negative Exponential Utility for Peanut Production.

Risk Premium

From figure 5.8, it is noticed that across all treatments, as producers become more risk averse they prefer to practice conventional tillage without cover crops than strip tillage with cover crops. For a risk neutral producer (ARAC = 0.00), shifting from the control to a treatment with cover crops earns them a loss of at least $91.34 per hectare for Mix treatment and at most $409.95 per hectare for the Rye and Crimson Clover only treatment. At the highest level of risk aversion (ARAC = 0.0010), shifting from the control to a treatment with cover crops earns them a loss of at least $76.25 per hectare for the Mix treatment and at most $398.94 per hectare for the Rye and Crimson Clover only treatment.

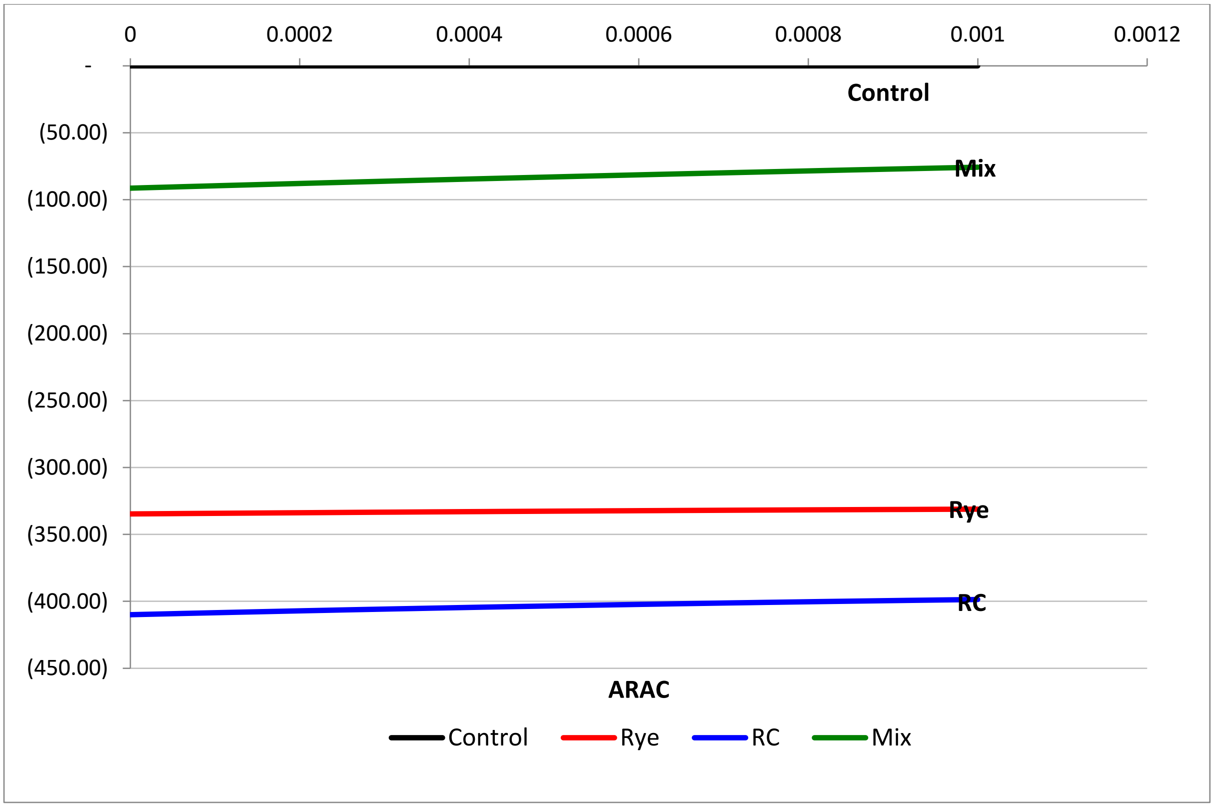


Figure 5.8. Negative Exponential Utility Weighted Risk Premiums Relative to Net Returns per Hectare for Peanut Production

Table 5.4 Utility Weighted Risk Premiums for Cover Crop Treatments Relative to Control under Peanut Production.

	Risk Neutral	*Somewhat Risk Averse*	*Rather Risk Averse*	*Very Risk Averse*	*Extremely Risk Averse*
	0.000	0.0002	0.0005	0.0007	0.0010
Risk Premiums for Control ($/ha)					
Rye Only	*($334.68)*	*($333.93)*	*($332.76)*	*($332.04)*	*($331.22)*
Rye and Crimson Clover	*($409.95)*	*($407.54)*	*($403.83)*	*($401.57)*	*($398.94)*
Mix	*($91.34)*	*($88.41)*	*($83.59)*	*($80.39)*	*($76.25)*

5.3 Cotton Results

Cotton Yield

From Table 5.5, the control had the highest average yield of 1381.48kg/ha followed by the Mix treatment with 1370.79kg/ha and Rye only treatment with 1352.98kg/ha, respectively. The Control treatment had the least standard deviation showing that its yields are the least volatile among all treatments followed by that of Mix treatment with a standard deviation of 155.15kg/ha. Hence, the highest yielding treatments are also the most stable in terms of yield variation. The Rye and Crimson Clover only treatment has the largest range and the highest standard deviation which shows that yields are very volatile under this treatment. The ANOVA results show that yields across treatments are not statistically different from each other.

Table 5.5 Summary Statistics of Cotton Yield Under the Different Treatments.

	Cotton (kg/ha)					
	Minimum	**Maximum**	**Mean**	**Standard Deviation**	**CV**	**ANOVA F – Statistic (P value)**
Control	1226.46	1684.88	1381.48	140.57	10.18	1.568 (NS) (0.219)
Rye	1063.39	1575.39	1352.98	170.77	12.62	
RC	970.95	1609.50	1221.42	200.11	16.38	
Mix	1244.87	1732.45	1370.79	155.15	11.32	

Note: "NS" means Not Statistically Significant and "CV" means Coefficient of Variation

Cotton Production Cost

As depicted by Figure 5.9, the Mix treatment has the highest cost of production with a total of $1,150.41 followed by the Rye and Crimson Clover only, Control and Rye only treatments with $1,153.86, $1135.23, and $1,134.27, respectively. It can also be noticed that like the case of corn, since almost all management practices were the same across all treatments, the major differences in cost were also driven by difference in treatment costs (cover crop and tillage costs) among treatments with cover crops. Treatments with cover crops except Rye only, had a higher cost of production. Also, just as in the case of corn and peanuts, the more cover crop species employed in a treatment, the more likely treatment costs and total production costs are going to increase.

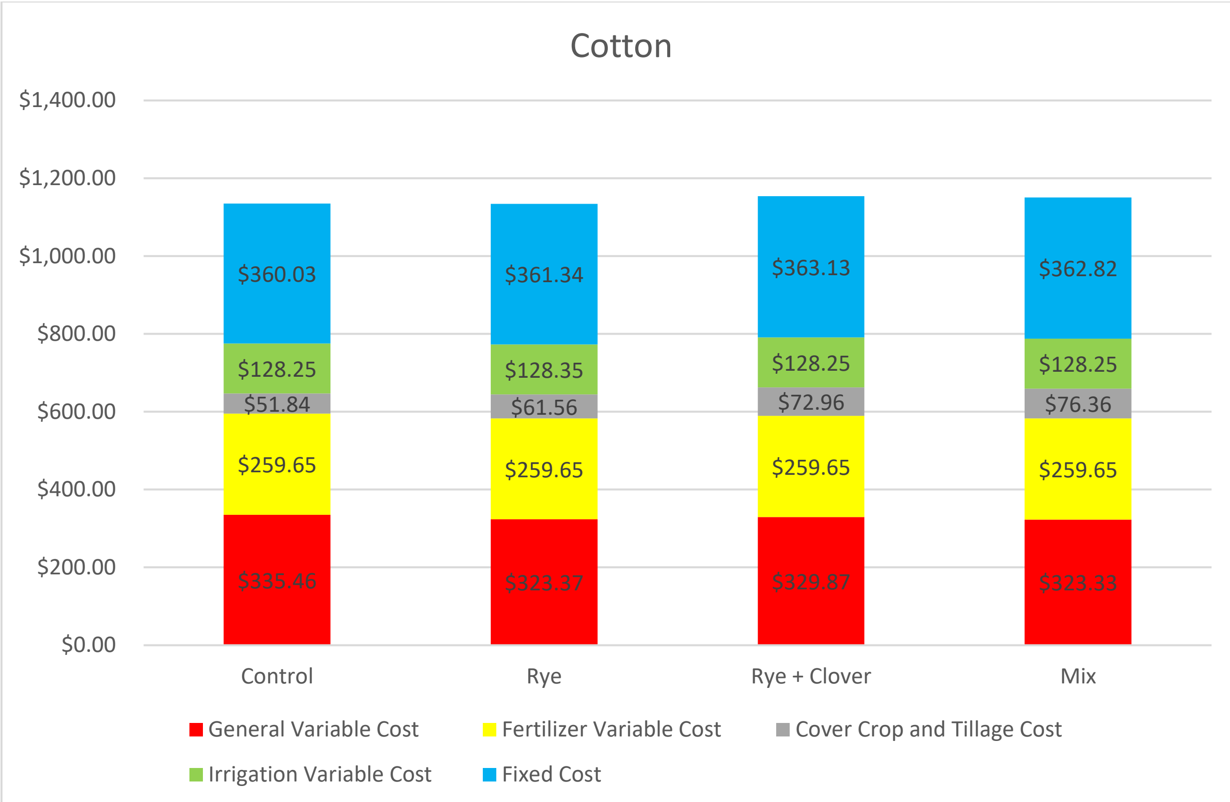


Figure 5.9 Cotton Production Costs Across all Treatments

Distribution of Cotton Net Returns

The reference net returns for the stoplight chart analysis of peanut were $1,835.38 (25th Percentile) and $2,292.88 (75th Percentile). From figure 5.10, Rye and Crimson Clover only have the most unfavorable distribution of net returns. It has the lowest probability of getting a net return greater than the upper value (13%) and the highest probability of generating a net return less than the lower value (50%). The Control and Rye only treatments have the highest probability of generating a net return higher than the upper value (38%). The Control and Mix treatments both have the lowest probability of generating a net return less than the lower value (13%). Risk averse producers will favor the Control treatment as it provides the best of both worlds (the highest probability of getting a favorable return coupled with the lowest probability to generate an unfavorable return).

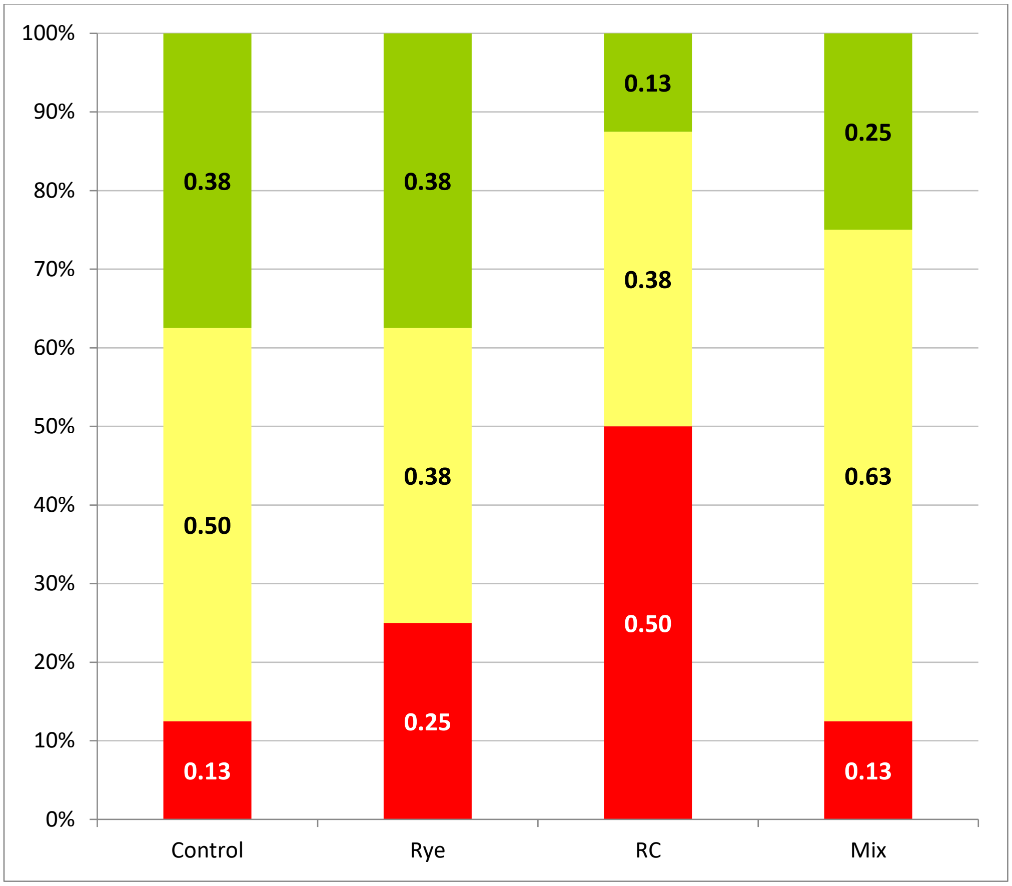


Figure 5.10. Stoplight Chart of Cotton Net Returns

Stochastic Efficiency with Respect to a Function (SERF)

Certainty Equivalent

The downward trend of the curves in Figure 5.11 shows that just like corn and peanut, as ARAC or risk aversion increases, certainty equivalent across all treatments tend to also decrease. It can be noticed that the certainty equivalent for the control treatment is the highest across all risk aversion levels, ranging from $2,109.94 to $2,197.71. This means the control treatment is the most preferred treatment by producers while Rye and Crimson Clover only treatment is the least preferred treatment by producers as it has the lowest certainty equivalents across all levels of risk aversion. The certainty equivalent of Rye only ranges from $2,051.68 to $2,155.89 while that of the Mix treatment ranges from $2,065.22 to $2,149.16. Between those two treatments, depending on a producer's level of risk aversion, the Mix treatment, or the Rye only treatment is preferred. From Table 5.6, it is noticed that risk neutral and somewhat risk averse producers prefer to practice the Rye only treatment over the Mix treatment while for rather risk averse, very risk averse and extremely risk averse producers will prefer to practice the Mix treatment over the Rye only treatment.

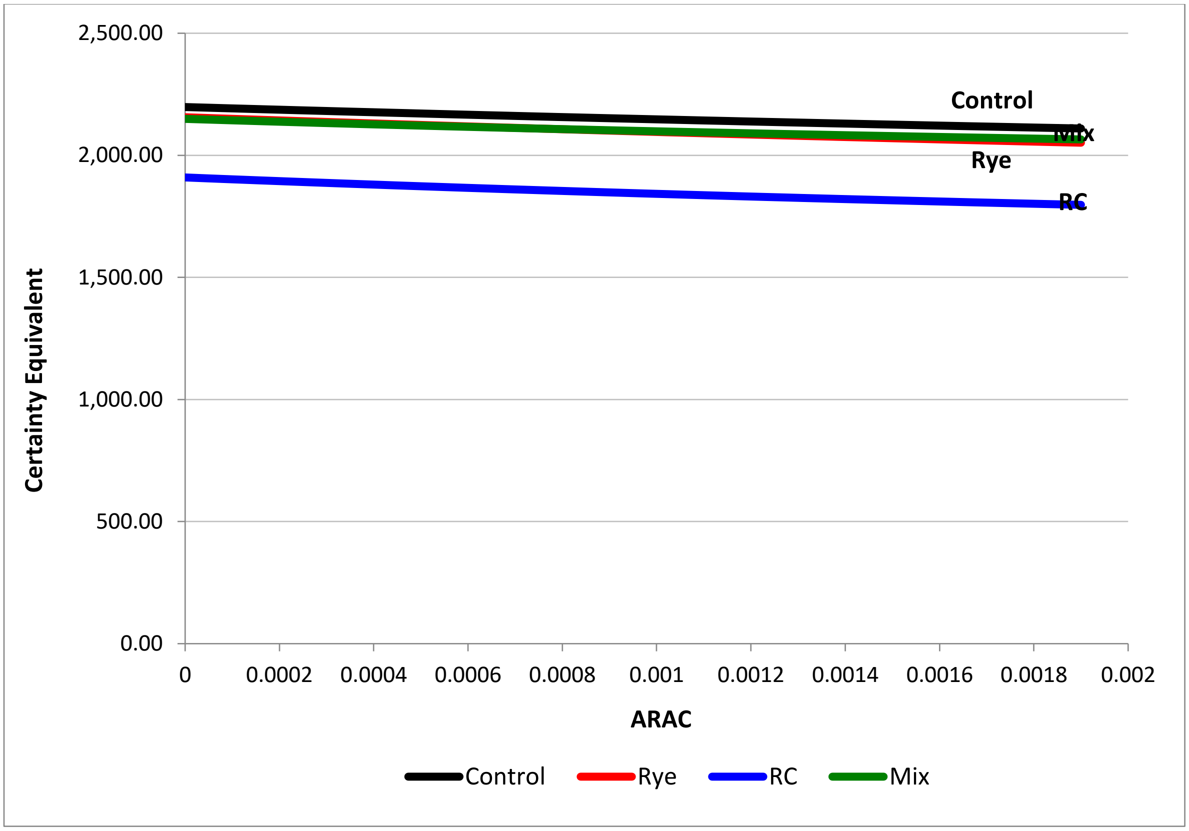


Figure 5.11. Stochastic Efficiency with Respect to a Function under Negative Exponential Utility for Cotton Production

Risk Premium

From figure 5.12, it is noticed that across all treatments, as producers become more risk averse they prefer to practice conventional tillage without cover crops than strip tillage with cover crops. For a risk neutral producer (ARAC = 0.00), shifting from the control to a treatment with cover crops earns them a loss of at least $41.82 per hectare for Rye only treatment and at most $288.38 per hectare for the Rye and Crimson Clover only treatment. At the highest level of risk aversion (ARAC = 0.0019), shifting from the control to a treatment with cover crops earns them a loss of at least $44.72 per hectare for the Mix treatment and at most $312.73 per hectare for the Rye and Crimson Clover only treatment.

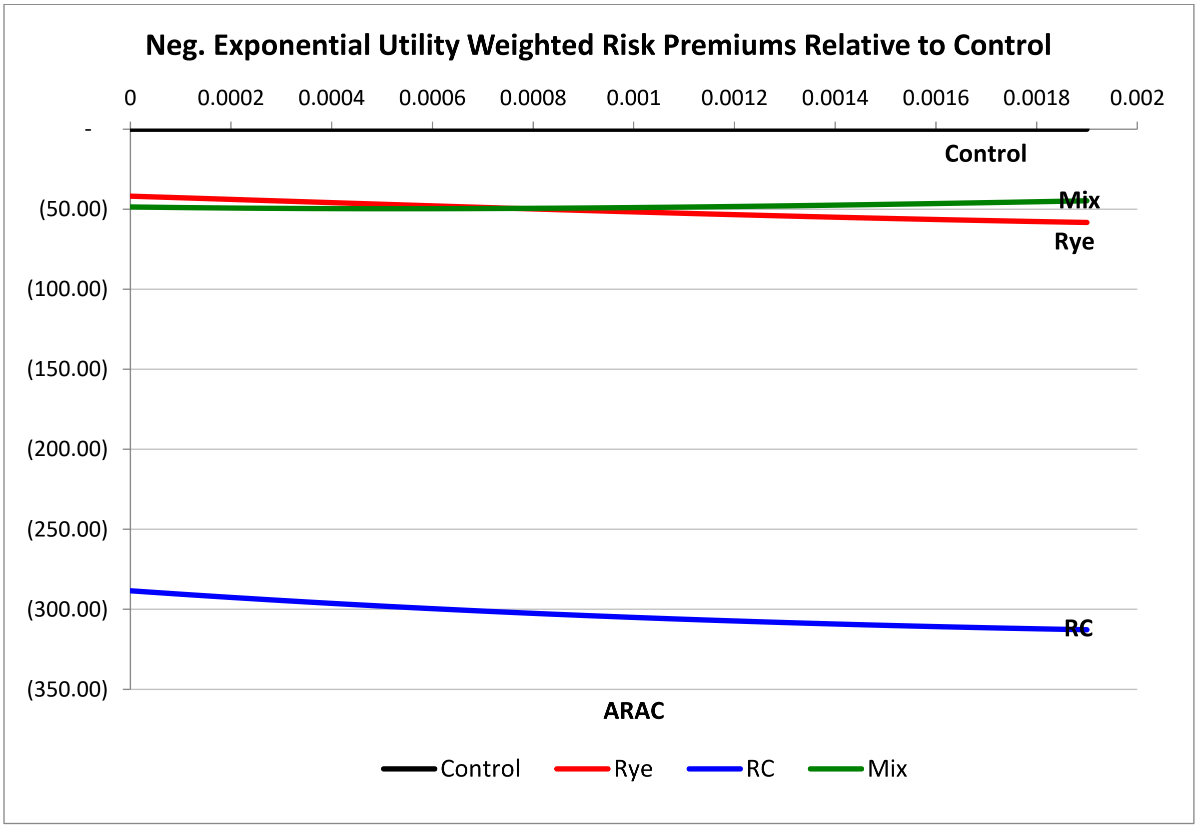


Figure 5.12. Negative Exponential Utility Weighted Risk Premiums Relative to Net Returns per Hectare for Cotton Production

Table 5.6 Utility Weighted Risk Premiums for Cover Crop Treatments Relative to Control under Peanut Production.

	Risk Neutral	*Somewhat Risk Averse*	*Rather Risk Averse*	*Very Risk Averse*	*Extremely Risk Averse*
	0.000	0.0005	0.0010	0.0014	0.0019
Risk Premiums for Control ($/ha)					
Rye Only	*($41.82)*	*($46.62)*	*($51.20)*	*($55.16)*	*($58.26)*
Rye and Crimson Clover	*($288.38)*	*($297.54)*	*($304.42)*	*($309.36)*	*($312.73)*
Mix	*($48.55)*	*($49.65)*	*($49.09)*	*($47.31)*	*($44.72)*

5.4 All Crops Results

Distribution of Net Returns

The reference net returns for the stoplight chart analysis of the pooled net returns of all crops under each treatment were $1,976.50 (25th Percentile) and $3,895.40 (75th Percentile). From figure 5.13, Rye only and Rye and Crimson Clover only had a 13% and 17% probability respectively of generating net returns greater than the upper value and a 25% and 33% chance respectively of generating a net return less than the lower value but a 63% and 50% probability respectively of generating a net return between the upper and lower value. Both the Mix and control treatment has the highest probability of giving a producer a favorable return (33%) but the Mix treatment also has a 29% probability of generating an unfavorable net return. The control treatment on the other hand has the least probability of generating an unfavorable net return (13%). Risk averse producers will favor the control treatments as it provides less risk in terms of the probability of obtaining a favorable net return.

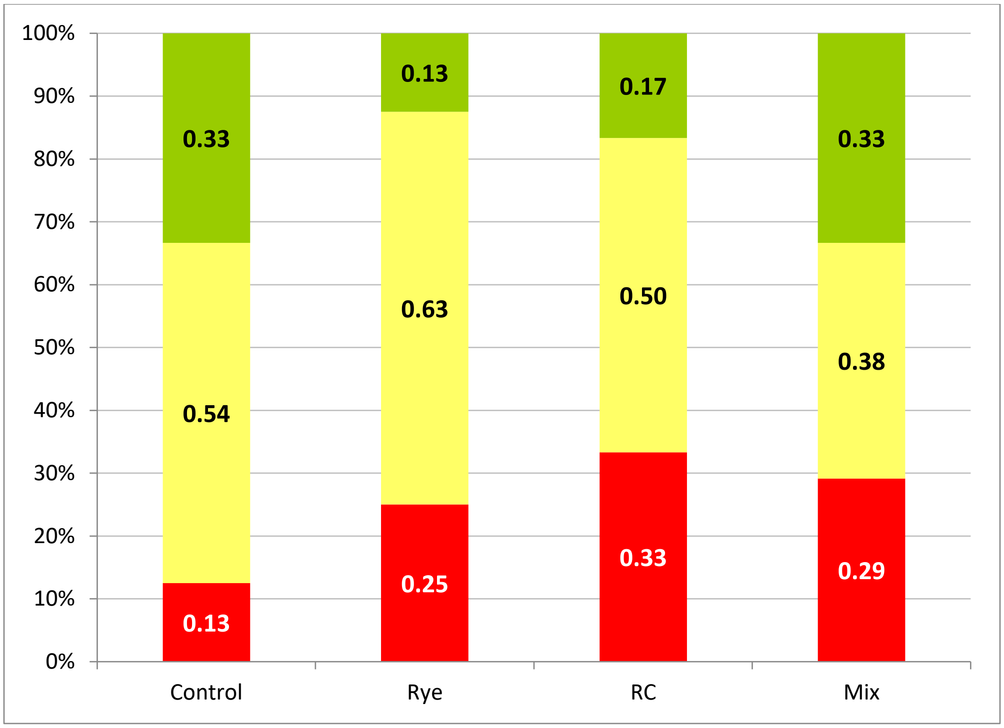


Figure 5.13. Stoplight Chart of Net Returns for All Crops

5.4.2 Stochastic Efficiency with Respect to a Function (SERF)

Certainty Equivalent

The downward trend of the curves in Figure 5.14 also show that as ARAC or risk aversion increases, certainty equivalent across all treatments tend to also decrease except that of the Rye only treatment. It can also be noticed that the certainty equivalent for the control treatment is the highest across all risk aversion levels, ranging from $3,068.88 to $2,564.15. The control treatment is the most preferred treatment by producers while Rye and Crimson Clover only treatment is still the least preferred treatment by producers as it has the lowest certainty equivalents across all levels of risk aversion. The certainty equivalent of the Mix treatment ranges from $3,012.30 to $2,443.32. It was the next best preferred treatment after the control treatment across all risk aversion levels.

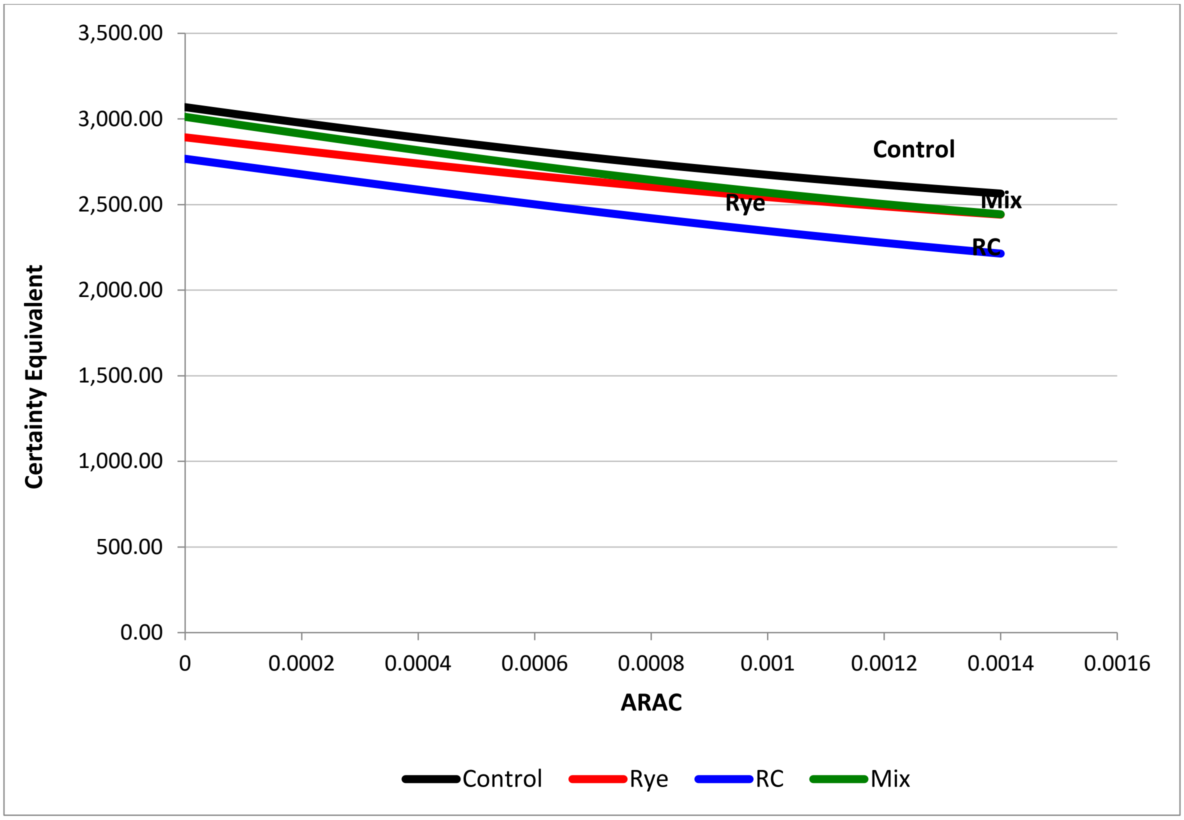


Figure 5.14. Stochastic Efficiency with Respect to a Function under Negative Exponential Utility for All Crops

Risk Premium

From figure 5.15, it is noticed that across all treatments, as producers become more risk averse the more they prefer to practice conventional tillage without cover crops than strip tillage with cover crops (except Rye only). For a risk neutral producer (ARAC = 0.00), shifting from the control to a treatment with cover crops earns them a loss of at least $56.58 per hectare for Mix treatment and at most $301.49 per hectare for the Rye and Crimson Clover only treatment. At the highest level of risk aversion (ARAC = 0.0014), shifting from the control to a treatment with cover crops earns them a loss of at least $120.83 per hectare for the Mix treatment and at most $350.44 per hectare for the Rye and Crimson Clover only treatment.

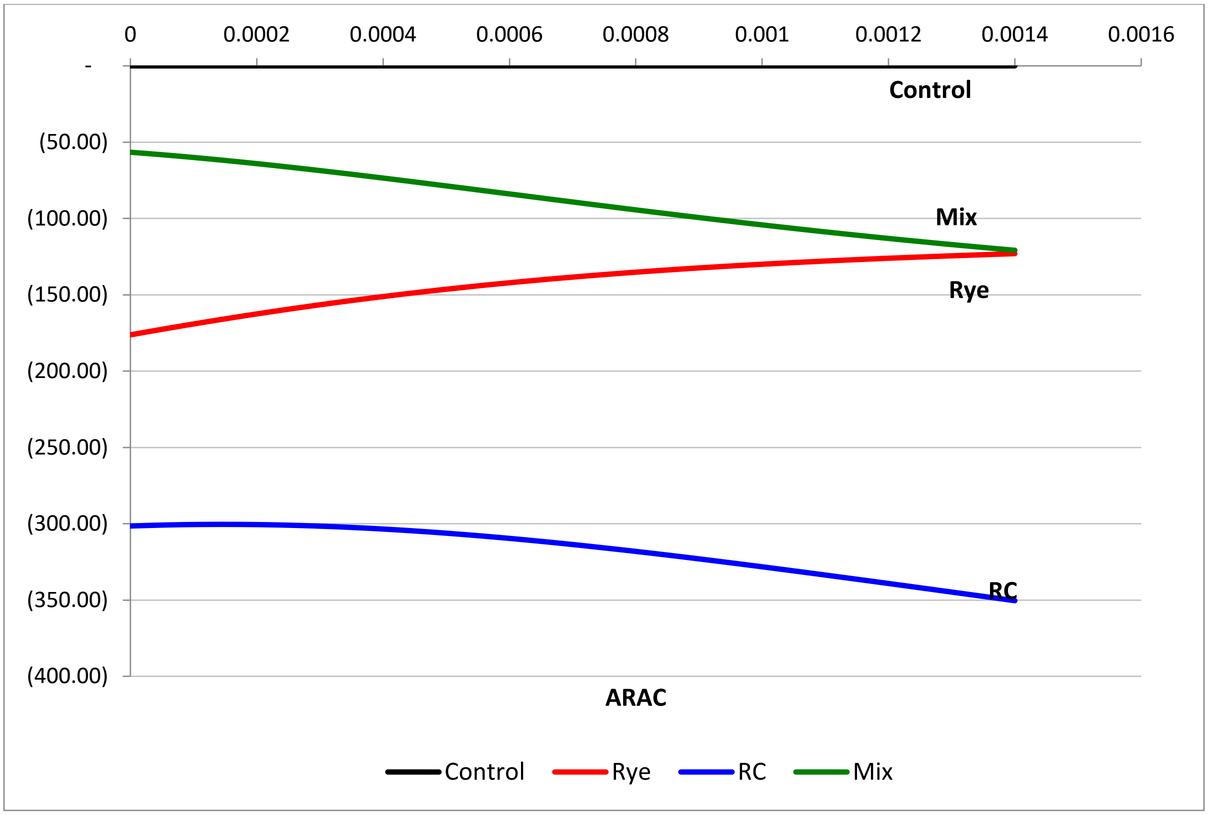


Figure 5.15. Negative Exponential Utility Weighted Risk Premiums Relative to Net Returns per Hectare for All Crops.

Table 5.7 Utility Weighted Risk Premiums for Cover Crop Treatments Relative to Control for All Crops.

	Risk Neutral	*Somewhat Risk Averse*	*Rather Risk Averse*	*Very Risk Averse*	*Extremely Risk Averse*
	0.000	0.0003	0.0007	0.0010	0.0014
Risk Premiums for Control ($/ha)					
Rye Only	*($176.24)*	*($157.01)*	*($138.41)*	*($130.16)*	*($123.04)*
Rye and Crimson Clover	*($301.49)*	*($301.47)*	*($313.64)*	*($327.79)*	*($350.44)*
Mix	*($56.58)*	*($68.20)*	*($89.18)*	*($103.81)*	*($120.83)*

5.5 Summary of Results

The analysis of yields from the experiment shows that across all the crops employed in the rotation, the Control treatment always has the highest yields on average followed by the Mix treatment. For both corn and cotton, the Control treatment has the least standard deviation and hence has the more stable yield while the Rye and Crimson Clover only treatment has the most volatile yield. For peanuts, the Mix treatment has the more stable yield while the Rye only treatment has the most volatile yield. There were also no significant differences in yields across treatments for corn and cotton but there were significant differences in yields found between the Control treatment and Rye and Crimson Clover only treatment in peanuts.

Results for the study also show that, under cost of production, the Mix treatment generally has a higher cost of production as it ranks first for corn and cotton and second for peanut production. The Control treatment's cost of production is highly driven by yield related costs hence, the higher the yield production the higher the total cost of production. Across all treatments involving cover crops, the more cover crops employed in the treatment, the more likely the treatment costs and total production costs are going increase.

Also, the results for the distribution of net returns for the crops show that peanuts have a higher net return in general. Across corn, peanut, and cotton, the Rye only and Rye and Crimson Clover only treatments usually have the highest probabilities of generating an unfavorable net return (a net return less than the lower cut-off value) and the least probability of generating a favorable net return (a net return greater than the upper cut-off value). For corn, the Mix treatment had the highest probability of generating a favorable net return, but it also had the highest probability of generating an unfavorable net return while the Control treatment had the second highest probability of generating a favorable net return and the least probability of generating an unfavorable net return. For both peanut and cotton, the Control treatment consistently provided the highest chance of generating a favorable return and the least chance of generating an unfavorable return. Hence, risk-averse farmers are going to prefer the Control treatment as it is likely to give a favorable return with less risk.

Generally, as Absolute Risk Aversion Coefficient (ARAC) or risk aversion increases, certainty equivalent across all treatments tend to decrease. For adoption of cover crops under risk aversion, across all crops and risk aversion levels, the Control treatment has the highest certainty equivalent (ranging from $2,729.33 to $2,503.34 for corn, $4,245.5 to $4,279.59 for peanut, and $2,109.94 to $2,197.71 for cotton). Hence, the Control treatment is the most preferred treatment for all crops under all levels of risk aversion while the Rye and Crimson Clover only treatment is the least preferred in the same vein. For adoption of treatments that include cover crops, the results show that for peanuts, the Mix treatment is the most preferred treatment across all risk aversion levels. For corn, risk neutral to very risk-averse producers prefer the Mix treatment, but extremely risk-averse producers prefer the Rye only treatment. On the other hand, for cotton, risk neutral to somewhat risk-averse producers prefer the Rye only treatment while rather risk-averse, very risk-averse, and extremely risk-averse producers prefer the Mix treatment.

CHAPTER 6
CONCLUSION

6.1 Farm-Scale Impacts

All cover crops treatments implemented were demonstrated to decrease yields on average in corn, peanut and cotton production as compared to the control treatment (no cover crop with conventional tillage) in the study region although the Mix cover crop treatment consistently performed the best among the cover crop treatments. Yield reductions in all three major crops under cover crop may be attributed to nutrient immobilization and hence the better performance of the Mix treatment can be attributed to having a legume in the mix which releases nitrogen to ameliorate the immobilization. However, the highest yielding cover crop treatment, the Mix treatment had higher cost of production which was driven by cover crop seed costs and harvest related costs as it produced higher yields on average than other cover crop treatments across all major crops. The control treatment also had high production costs per hectare across all major crops due to harvest-related costs per hectare as it produced the highest average yields under corn, peanuts, and cotton. Net returns are generally higher in peanut production, followed by corn and cotton production, respectively. The distribution of net returns for the Control treatment seems to be more favorable to risk-averse producers as they are more likely to generate favorable net returns, and consistently the least likely to generate unfavorable returns. The Rye and Crimson Clover only treatment is the least profitable as the extra cost incurred from the cover crop implementation does not reflect in its yields, leading to lower revenues and lower and unfavorable net returns.

6.2 Policy Implications

It was found that producers of corn, peanuts, and cotton, irrespective of their level of risk aversion, preferred the Control treatment—adding no cover crops along with conventional tillage. But more importantly, as governments encourage the adoption of cover crops, the study shows that the choice of cover crop treatment adopted by a farmer is dependent on their level of risk aversion and which main crop is to be planted after the cover crop. One of the primary governmental tools for altering producers' production methods is the subsidization of conservation technologies.

The adoption of a mix species of cover crops with strip tillage, was ranked as the most preferred cover crop treatment for corn producers except extremely risk-averse producers who prefer the Rye only treatment as the second best. The amount of the subsidy to incentivize corn growers to apply the mix treatment is calculated using the producers' typical practices, which are taken to be the conventional tillage combined with no cover crops. Producers implementing the Mix treatment would require a subsidy ranging from $29.85 to $245.25 per hectare, depending on their level of risk aversion. Producers implementing the Rye only treatment would need a subsidy from $152.22 to $208.38 per hectare while those who prefer to implement the Rye and Crimson Clover only treatment would need a subsidy from $206.14 and $427.54.

For peanut producers, producers currently practicing the Control treatment could be encouraged to adopt the most risk-efficient practice (the Mix treatment) through a subsidy between $76.25 and $91.34 per hectare. The Rye and Crimson Clover treatment was least preferred by peanut producers and hence, producers currently implementing rye and crimson clover with strip tillage would realize gains if they were to adopt the Mix treatment rather.

The adoption of the rye only cover crop with strip tillage, was ranked as the most preferred cover crop treatment for risk neutral to somewhat risk-averse cotton producers but rather risk-averse, very risk-averse, and extremely risk-averse producers prefer the Mix treatment. Producers implementing the Mix treatment would require a subsidy ranging from $44.72 to $48.55 per hectare, depending on their level of risk aversion. Producers implementing the Rye only treatment would need a subsidy from $41.82 to $58.26 per hectare while those who prefer to implement the Rye and Crimson Clover only treatment would need a subsidy from $288.38 and $312.73.

Therefore, to efficiently design conservation programs that promote cover crop adoption, policy makers may have to invest in research that elicit the risk preferences of farmers or producers to better tailor programs to these farmers if the programs are to be successfully adopted by farmers. But if a farmer wants a blanket cover crop practice to adopt without regard for risk aversion level or main crop to be planted, the best choice will be the Mix treatment as it is consistently the highest yielding and is the most preferred cover crop treatment across most risk aversion levels and main crops and the few times the Rye only treatment was preferred over it, the difference in risk premium was small.

In Georgia, agriculture is a vital industry, and the use of sustainable production methods is growing in significance. Cover crop and conservation tillage adoption can maintain profitable production of corn, peanut, and cotton while providing long production sustainability. This study determined the risk-efficient technique for producing corn, peanuts, and cotton while assessing the effects at the farm level of using strip tillage with single and multispecies cover crops. The typical practice of no cover crops with conventional tillage is the most risk-efficient practice, but for the promotion of long-term production sustainability, the adoption of mix species of cover crops with strip tillage more consistently ranks as the second most efficient practice. Also, due to the lower risk premiums involved with this practice, it will be the most cost-effective practice for subsidy policies to be designed around.

REFERENCES

Abdalla, M., Hastings, A., Cheng, K., Yue, Q., Chadwick, D., Espenberg, M., Truu, J., Rees, R. M., & Smith, P. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. Global Change Biology, 25(8), 2530–2543. https://doi.org/10.1111/gcb.14644

Achankeng, E., & Cornelis, W. (2023). Conservation tillage effects on European crop yields: A meta-analysis. *Field Crops Research*, *298*, 108967. https://doi.org/10.1016/j.fcr.2023.108967

Acuña, J. C. M., & Villamil, M. B. (2014). Short-Term effects of cover crops and compaction on soil properties and soybean production in Illinois. *Agronomy Journal*, *106*(3), 860–870. https://doi.org/10.2134/agronj13.0370

Adetunji, A. T., Ncube, B., Mulidzi, A., & Lewu, F. B. (2020). Management impact and benefit of cover crops on soil quality: A review. *Soil and Tillage Research*, *204*, 104717. https://doi.org/10.1016/j.still.2020.104717

Adeux, G., Cordeau, S., Antichi, D., Carlesi, S., Mazzoncini, M., Munier-Jolain, N., & Bàrberi, P. (2021). Cover crops promote crop productivity but do not enhance weed management in tillage-based cropping systems. *European Journal of Agronomy*, *123*, 126221. https://doi.org/10.1016/j.eja.2020.126221

Adusumilli, N., Wang, H., Dodla, S., & Deliberto, M. (2020). Estimating risk premiums for adopting no-till and cover crops management practices in soybean production system using stochastic efficiency approach. *Agricultural Systems*, *178*, 102744. https://doi.org/10.1016/j.agsy.2019.102744

Ali, A. B., Elshaikh, N. A., Li, H., Adam, A. B., & Yan, H. (2016). Conservation tillage as an approach to enhance crops water use efficiency. *Acta Agriculturæ Scandinavica. Section B, Soil and Plant Science*, *67*(3), 252–262. https://doi.org/10.1080/09064710.2016.1255349

Anapalli, S. S., Reddy, K. N., & Jagadamma, S. (2018). Conservation tillage impacts and adaptations in irrigated corn production in a humid climate. *Agronomy Journal*, *110*(6), 2673–2686. https://doi.org/10.2134/agronj2018.03.0195

Anderson, J. R., & Dillon, J. L. (1992). *Risk analysis in dryland farming systems* (Issue 1). http://ci.nii.ac.jp/ncid/BA25442443

Arbuckle, J. G., & Roesch-McNally, G. (2015). Cover crop adoption in Iowa: The role of perceived practice characteristics. *Journal of Soil and Water Conservation*, *70*(6), 418–429. https://doi.org/10.2489/jswc.70.6.418

Arrow, K. J. (1965). Aspects of the theory of risk-bearing. Helsinki: Yrjö Jahnssonin Säätiö.

Arrow, K. J. (1965). *Aspects of the theory of risk-bearing*. Yrjö Jahnssonin Säätiö.

Awondo, S. N., Fonsah, E. G., & Gray, D. J. (2017). “Incorporating Structure and Stochasticity in Muscadine Grape Enterprise Budget and Investment Analysis.” *HortTechnology*, *27*(2), 212 – 222. https://doi.org/10.21273/horttech03466-16

Babcock, B. A., & Shogren, J. F. (1995). The cost of agricultural production risk. *Agricultural Economics*, *12*(2), 141–150. https://doi.org/10.1111/j.1574-0862.1995.tb00358.x

Babcock, B. A., Choi, E. K., & Feinerman, E. (1993). Risk and Probability Premiums for CARA Utility Functions. *Journal of Agricultural and Resource Economics*, *18*(1), 17–24. https://doi.org/10.22004/ag.econ.30810

Basche, A., Archontoulis, S. V., Kaspar, T. C., Jaynes, D. B., Parkin, T. B., & Miguez, F. E. (2016). Simulating long-term impacts of cover crops and climate change on crop production and environmental outcomes in the Midwestern United States. *Agriculture, Ecosystems & Environment*, *218*, 95–106. https://doi.org/10.1016/j.agee.2015.11.011

Bhattarai, A., Liu, Y., Liakos, V., & Vellidis, G. (2020). Economic Analysis of Modern Irrigation Scheduling Strategies on Cotton Production Under Different Tillage Systems in South Georgia.".

Blanco-Canqui, H. (2018). Cover crops and water quality. Agronomy Journal, 110(5), 1633–1647. https://doi.org/10.2134/agronj2018.02.0077

Burke, J. A., Lewis, K. L., Ritchie, G. L., DeLaune, P. B., Keeling, J. W., Acosta-Martínez, V., Moore, J. M., & McLendon, T. (2021). Net positive soil water content following cover crops with no tillage in irrigated semi-arid cotton production. *Soil & Tillage Research*, *208*, 104869. https://doi.org/10.1016/j.still.2020.104869

Busari, M. A., Kukal, S. S., Kaur, A., Bhatt, R., & Dulazi, A. A. (2015). Conservation tillage impacts on soil, crop and the environment. *International Soil and Water Conservation Research/International Soil and Water Conservation Research*, *3*(2), 119–129. https://doi.org/10.1016/j.iswcr.2015.05.002

Byrd, M. 2005. “A Farm-Level Approach to the Methyl Bromide Phase-Out: Identifying Alternatives and Maximizing Net Worth Using Stochastic Dominance and Optimization Procedures.” MS Thesis, University of Georgia, Athens, GA.

Campbell, K. M., Boyer, C. N., Lambert, D. M., Clark, C. D., & Smith, S. A. (2021). Risk, cost-share payments, and adoption of cover crops and no-till. *Journal of Soil and Water Conservation*, *76*(2), 166–174. https://doi.org/10.2489/jswc.2021.00027

Cochran, M. J., Robison, L. J., & Lodwick, W. (1985). Improving the Efficiency of Stochastic Dominance Techniques Using Convex Set Stochastic Dominance. *American Journal of Agricultural Economics*, *67*(2), 289–295. https://doi.org/10.2307/1240681

D’Emden, F., Llewellyn, R., & Burton, M. (2008b). Factors influencing adoption of conservation tillage in Australian cropping regions*. *Australian Journal of Agricultural and Resource Economics*, *52*(2), 169–182. https://doi.org/10.1111/j.1467-8489.2008.00409.x

Delgado, J. A., & Gantzer, C. J. (2015). The 4Rs for cover crops and other advances in cover crop management for environmental quality. *Journal of Soil and Water Conservation*, *70*(6), 142A-145A. https://doi.org/10.2489/jswc.70.6.142a

Dillon, C. (1993). “Advanced breakeven analysis of agricultural enterprise budgets”. *Agricultural Economics*, *9*(2), 127–143. https://doi.org/10.1016/0169-5150(93)90008-z

Doye, D. & Sahs, R. (2005). “Using Enterprise Budgets in Farm Financial Planning”. Oklahoma Cooperative Extension Service, Oklahoma State University.

Dozier, I. A., Behnke, G. D., Davis, A. S., Nafziger, E. D., & Villamil, M. B. (2017). Tillage and cover cropping effects on soil properties and crop production in Illinois. Agronomy Journal, 109(4), 1261–1270. https://doi.org/10.2134/agronj2016.10.0613

Dunn, K. C. (2008). "Evaluating the Profitability of Pearl Millet as a Nutrient Management Practice Based on Two Case Study Farms in the Southeastern Piedmont Region of Georgia" MS Thesis, University of Georgia, Athens, GA.

Economic Research Service (2024 January, 12). Ag and Food Sectors and the Economy. *United States Department of Agriculture*, https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/#:~:text=Agriculture%2C%20food%2C%20and%20related%20industries%20contributed%205.4%20percent,food%20programs%2C%20nutrition%20assistance%20far%20outpaces%20other%20programs.

Essah, S. Y. C., Delgado, J. A., Dillon, M. A., & Sparks, R. T. (2012). Cover crops can improve potato tuber yield and quality. *Horttechnology*, *22*(2), 185-190. https://doi.org/10.21273/horttech.22.2.185

Evans, E. A., & Garcia, S. (2016). Assessing the profitability of guava production in South Florida under risk and uncertainty. *Journal of Extension*, *54*(1). https://doi.org/10.34068/joe.54.01.17

Fan, Y., Liu, Y., DeLaune, P. B., Mubvumba, P., Park, S. C., & Bevers, S. J. (2020). Economic analysis of adopting no-till and cover crops in irrigated cotton production under risk. *Agronomy Journal*, *112*(1), 395–405. https://doi.org/10.1002/agj2.20005

Fan, Y., Liu, Y., DeLaune, P. B., Mubvumba, P., Park, S. C., & Bevers, S. J. (2020). Net return and risk analysis of winter cover crops in dryland cotton systems. *Agronomy Journal*, *112*(2), 1148–1159. https://doi.org/10.1002/agj2.20091

Fonsah, E.G., and K. Rucker. "Bell Pepper on Plastic Enterprise Budget," Department of Agricultural and Applied Economics, University of Georgia, 2003.

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. M. (2015). Coping with risk in agriculture: Applied decision analysis (3rd ed). Cambridge, MA: CABI Publication

Hardaker, J. B., Richardson, J. W., Lien, G., & Schumann, K. D. (2004). Stochastic efficiency analysis with risk aversion bounds: a simplified approach. *Australian Journal of Agricultural and Resource Economics*, *48*(2), 253–270. https://doi.org/10.1111/j.1467-8489.2004.00239.x

He, C., Niu, J., Xu, C., Han, S., Bai, W., Song, Q., Dang, Y. P., & Zhang, H. (2022). Effect of conservation tillage on crop yield and soil organic carbon in Northeast China: A meta-analysis. *Soil Use and Management*, *38*(2), 1146–1161. https://doi.org/10.1111/sum.12784

Hignight, J. A., Watkins, K. B., & Anders, M. M. (Eds.). (2010, February 6-9). *An Economic Risk Analysis of Tillage and Cropping Systems on the Arkansas Grand Prairie*. SAEA Annual Meeting, Orlando, FL, United States. https://doi.org/10.22004/ag.econ.56354

Jacobs, A., Evans, R., Allison, J. K., Garner, E. R., Kingery, W. L., & McCulley, R. L. (2022). Cover crops and no-tillage reduce crop production costs and soil loss, compensating for lack of short-term soil quality improvement in a corn and soybean production system. *Soil & Tillage Research*, *218*, 105310. https://doi.org/10.1016/j.still.2021.105310

Jug, D., Đurđević, B., Birkáš, M., Brozović, B., Lipiec, J., Vukadinović, V., & Jug, I. (2019). Effect of conservation tillage on crop productivity and nitrogen use efficiency. *Soil & Tillage Research*, *194*, 104327. https://doi.org/10.1016/j.still.2019.104327

Kahan, D. (2008). Managing Risk in Farming. *Food and Agriculture Organization of the United Nations*

Kane P. Sharon (2022). University of Georgia Agsnapshots. *Center for Agribusiness and Economic Development*. Retrieved January 18, 2024, from https://caed.uga.edu/content/dam/caessubsite/caed/publications/agsnapshots/2022CAEDAgSnapshotsWeb.pdf#:~:text=In%202020%2C%20agriculture%20contributed%20%2469.4%20billion,in%20output%20to%20Georgia%E2%80%99s%20%241.1%20trillion%20economy.

Kathage, J., Smit, B., Janssens, B., Haagsma, W., & Adrados, J. L. (2022). How much is policy driving the adoption of cover crops? Evidence from four EU regions. *Land Use Policy*, *116*, 106016. https://doi.org/10.1016/j.landusepol.2022.106016

Koudahe, K., Allen, S., & Djaman, K. (2022). Critical review of the impact of cover crops on soil properties. *International Soil and Water Conservation Research*, *10*(3), 343 - 354. https://doi.org/10.1016/j.iswcr.2022.03.003

Langemeier, M. "Using Enterprise Budgets to Compute Crop Breakeven Prices." farmdoc daily (5):195, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, October 21, 2015.

Laporte, J. & McKendree, M. "Enterprise Budgets are Useful Tools Especially During Uncertain Times". Department of Agriculture, Food, and Resource Economics, Michigan State University, October 25, 2021.

Lee, S., & McCann, L. (2019). Adoption of cover crops by U.S. soybean producers. *Journal of Agricultural and Applied Economics*, *51*(04), 527–544. https://doi.org/10.1017/aae.2019.20

Liu, T., Bruins, R. J. F., & Heberling, M. T. (2018). Factors Influencing Farmers' Adoption of Best Management Practices: A Review and Synthesis. Sustainability, 10(2), 432. https://doi.org/10.3390/su10020432

Liu, Y., Langemeier, M. R., Small, I. M., Joseph, L., Fry, W. E., Ristaino, J. B., Saville, A., Gramig, B. M., & Preckel, P. V. (2018). A risk analysis of precision agriculture Technology to manage tomato late blight. *Sustainability*, *10*(9), 3108. https://doi.org/10.3390/su10093108

Menapace, L., Colson, G., & Raffaelli, R. (2013). Risk Aversion, Subjective Beliefs, and Farmer Risk Management Strategies. *American Journal of Agricultural Economics*, *95*(2), 384–389.

Mirsky, S. B., Ryan, M. R., Curran, W. S., Teasdale, J. R., Maul, J. E., Spargo, J. T., Moyer, J., Grantham, A. M., Weber, D. C., Way, T. R., & Camargo, G. (2012). Conservation tillage issues: Cover crop-based organic rotational no-till grain production in the mid-Atlantic region, USA. *Renewable Agriculture and Food Systems*, *27*(1), 31-40. https://doi.org/10.1017/s1742170511000457

Mulvaney, M. and Devkota, P. (2020). Adjusting Crop Yield to a Standard Moisture Content. (No. SS-AGR-443). University of Florida Cooperative Extension Service. Retrieved March 25, 2023 from https://edis.ifas.ufl.edu/publication/AG442

Mwinuka, L., Mutabazi, K. D., Sieber, S., Makindara, J., & Bizimana, J. (2017). An economic risk analysis of fertiliser microdosing and rainwater harvesting in a semi-arid farming system in Tanzania. *Agrekon*, *56*(3), 274–289. https://doi.org/10.1080/03031853.2017.1343154

Page, K., Dang, Y. P., & Dalal, R. C. (2013). Impacts of conservation tillage on soil quality, including soil-borne crop diseases, with a focus on semi-arid grain cropping systems. *Australasian Plant Pathology*, *42*(3), 363–377. https://doi.org/10.1007/s13313-013-0198-y

Parr, M. K., Grossman, J., Reberg-Horton, S. C., Brinton, C. M., & Crozier, C. R. (2011). Nitrogen Delivery from Legume Cover Crops in No-Till Organic Corn Production. *Agronomy Journal*, *103*(6), 1578–1590. https://doi.org/10.2134/agronj2011.0007

Pramanick, B., Kumar, M., Naik, B. M., Kumar, M., Singh, S. K., Maitra, S., Naik, B. S. S. S., Rajput, V. D., & Minkina, T. (2022). Long-Term conservation tillage and precision nutrient management in Corn–Wheat cropping system: effect on soil properties, crop production, and economics. *Agronomy*, *12*(11), 2766. https://doi.org/10.3390/agronomy12112766

Pratt, J. W. (1964). Risk aversion in the small and in the large. *Econometrica*, *32*(1/2), 122. https://doi.org/10.2307/1913738

Raper, R., Reeves, D., Burmester, C. and Schwab, E. (2000). Tillage Depth, Tillage Timing, and Cover Crop Effects on Cotton Yield, Soil Strength, and Tillage Energy Requirements. Applied Engineering in Agriculture, 16(4): 379-385. doi: 10.13031/ 2013.5363

Raskin, R., & Cochran, M. J. (1986). Interpretations and transformations of scale for the Pratt-Arrow absolute risk aversion coefficient: Implications for generalized stochastic dominance. Western Journal of Agricultural Economics, 204–210. https://www.jstor.org/stable/40987816

Reese, C. L., Clay, D. E., Clay, S. A., Bich, A. D., Kennedy, A. C., Hansen, S. A., & Moriles, J. (2014). Winter cover crops impact on corn production in semiarid regions. Agronomy Journal, 106(4), 1479–1488. https://doi.org/10.2134/agronj13.0540

Reicosky, D. C. (2015). Conservation tillage is not conservation agriculture. *Journal of Soil and Water Conservation*, *70*(5), 103A-108A. https://doi.org/10.2489/jswc.70.5.103a

Richardson, J. W. (2010). Simulation for applied risk management with an introduction to SIMETAR©. College Station, TX: Department of Agricultural Economics, Texas A&M University

Richardson, J. W., & Outlaw, J. L. (2008). Ranking risky alternatives: Innovations in subjective utility analysis. Communications Technology, 39, 213–224.

Richardson, J. W., Lemmer, W. J., & Outlaw, J. L. (2007). Bio-ethanol production from wheat in the winter rainfall region of South Africa: A quantitative risk analysis. International Food Agribusiness Management Review, 10(2), 181–204.

Richardson, J. W., Schumann, K. D., & Feldman, P. A. (2006). Simetar: Simulation for Excel to analyze risk. College Station, TX: Texas A&M University.

Richardson, J. W., Schumann, K., & Feldman, P. (2008). Simulation and econometrics to analyze risk. *2006 Simetar User's Manual*.

Roesch-McNally, G., Basche, A., Arbuckle, J. G., Tyndall, J., Miguez, F. E., Bowman, T., & Clay, R. (2017). The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. *Renewable Agriculture and Food Systems*, *33*(4), 322-333. https://doi.org/10.1017/s1742170517000096

Schipanski, M., Barbercheck, M. E., Douglas, M. R., Finney, D. M., Haider, K. R., Kaye, J. P., Kemanian, A. R., Mortensen, D. A., Ryan, M. R., Tooker, J. F., & White, C. (2014). A framework for evaluating ecosystem services provided by cover crops in agroecosystems. *Agricultural Systems*, *125*, 12–22. https://doi.org/10.1016/j.agsy.2013.11.004

Simtowe, F. (2006). *Can Risk-Aversion Towards Fertilizer Explain Part of the Non-Adoption Puzzle for Hybrid Corn? Empirical Evidence from Malawi* (SSRN Scholarly Paper No. 939398). Social Science Research Network. https://papers.ssrn.com/abstract=939398

Sun, L., Wang, S., Zhang, Y., Li, J., Wang, X., Wang, R., Lyu, W., Chen, N., & Wang, Q. (2018). Conservation agriculture based on crop rotation and tillage in the semi-arid Loess Plateau, China: Effects on crop yield and soil water use. *Agriculture, Ecosystems & Environment*, *251*, 67–77. https://doi.org/10.1016/j.agee.2017.09.011

The Georgia Conservancy (2023 January, 12). The Importance of Georgia's Agricultural Lands. *Saporta Report*, https://saportareport.com/the-importance-of-georgias-agricultural-lands/thought-leadership/the-georgia-conservancy/

Tostensen, M. L. (2023). Long-Term Cover Crop Analysis in the Coastal Plains Crop Production Region to Compare Cover Crop Treatments and Retained In-Season Soil Moisture [Masters dissertation, The University of Georgia]. ProQuest Dissertations and Theses database. https://esploro.libs.uga.edu/esploro/outputs/graduate/LONG-TERM-COVER-CROP-ANALYSIS-IN-THE/9949559230002959?institution=01GALI_UGA

UGA Extension. (2022). Assisting Georgia Farmers with Irrigation Scheduling Retrieved March 25, 2023 from https://extension.uga.edu/about/our-impact/impact-stories/impact-statement/10009/assisting-georgia-farmers-with-irrigation-scheduling.html

UGA Extension. (2023). Georgia Pest Management Handbook. Retrieved April 5, 2023 from https://ipm.uga.edu/georgia-pest-management-handbook/

USDA-NASS. (2023). Quick Stats. 2017 Census of Agriculture: United States Summary and State Data.

USDA-National Agricultural Statistics Service (2020). 2017 Agriculture Census. *United States Department of Agriculture,* *https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Census_by_State/index.php*

Van Den Putte, A., Govers, G., Diels, J., Gillijns, K., & Demuzere, M. (2010). Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture. *European Journal of Agronomy*, *33*(3), 231–241. https://doi.org/10.1016/j.eja.2010.05.008

Varian, H. R. (1992). Microeconomic analysis (3rd ed.). New York, NY: Norton.

Vulchi, R., Zapata, S. D., Nolte, S. A., Robinson, J. R., & McGinty, J. (2023). Dicamba-Based Herbicide Programs, cropping sequences, Tillage Types in Cotton – Profitability and Risk Efficiency analysis. *Journal of Cotton Science*, *27*(4), 158–172.

Wang, W., Yuan, J., Gao, S., Li, T., Li, Y., Nangia, V., Mo, F., Liao, Y., & Wen, X. (2020). Conservation tillage enhances crop productivity and decreases soil nitrogen losses in a rainfed agroecosystem of the Loess Plateau, China. *Journal of Cleaner Production*, *274*, 122854. https://doi.org/10.1016/j.jclepro.2020.122854

Watkins, K. B., Gealy, D. R., Anders, M. M., & Mane, R. U. (2018). An Economic Risk Analysis of Weed-Suppressive Rice Cultivars in Conventional Rice Production. *Journal of Agricultural and Applied Economics*, *50*(4), 478–502. https://doi.org/10.1017/aae.2018.9

Watkins, K. B., Hignight, J. A., Beck, P. A., Anders, M. M., Hubbell, D. S., & Gadberry, S. (Eds.). (2010). *An Economic Risk Analysis of Stocker Grazing on Conservation Tillage Small Grains Forage in Arkansas*. https://doi.org/10.22004/ag.econ.56356

Williams, J. R., Pachta, M. J., Roozeboom, K. L., Llewelyn, R. V., Claassen, M. M., & Bergtold, J. S. (2012). Risk Analysis of Tillage and Crop Rotation Alternatives with Winter Wheat. *Journal of Agricultural and Applied Economics*, *44*(4), 561–576. https://doi.org/10.1017/S1074070800024111

Williams, J. R., Saffert, A. T., Barnaby, G. A., Llewelyn, R. V., & Langemeier, M. R. (2014). A risk analysis of Adjusted Gross Revenue-Lite on beef farms. *Journal of Agricultural and Applied Economics*, *46*(2), 227–244. https://doi.org/10.1017/s1074070800000754

Wittwer, R. A., Dorn, B., Jossi, W., & Van Der Heijden, M. G. A. (2017). Cover crops support ecological intensification of arable cropping systems. *Scientific Reports*, *7*(1). https://doi.org/10.1038/srep41911