Farm-Scale Economic Analysis of Best Management Practices for Cotton and Peanut Production

by

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ABSTRACT

Agriculture is a vital industry in the state of Georgia; therefore, the sustainability of agricultural production is critical to the area. Best management practices (BMPs) can decrease production inputs, aiding in reducing agricultural pollution, often without reducing farm productivity. Additionally, more efficient resource use can help to combat rising input prices. However, concern about the impacts of BMP adoption on yield and profitability can hinder producers' decision to adopt. Current literature on BMP adoption is evaluated at the individual conservation technique and fails to address a bundle of BMP's joint effects on yield and profitability, and the risk attitudes of producers. To quantify the risk of BMP implementation for cotton and peanut production in Georgia, we investigated the variability in net returns between alternative BMP systems. Data were collected from producers and extension agents to create enterprise budgets to represent current land-use practices in the region, including farm-scale production costs for management systems that were evaluated at three scenario levels: intensive, typical, and minimal adoption of BMP technologies and practices. Using Simetar modeling software, we simulated net returns to compare alternative scenarios and stochastically determine the financial viability of BMP adoption. Stochastic efficiency with respect to a function (SERF) was used to rank cotton and peanut BMP bundles in terms of certainty equivalents at each level of absolute risk aversion. This research aims to determine the economic sustainability of BMP bundles by evaluating changes in net returns when a BMP system is adopted and identifying the risk-efficient management system. Findings indicate that, as producers' risk-aversion grows, the typical BMP system becomes the most preferred by both peanut and cotton producers. The results can inform grower decision-making about regional BMP adoption.

INDEX WORDS: Cotton, Peanut, Best Management Practices, Budgets, Risk, Stochastic Efficiency with Respect to a Function

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Chapter 1

Introduction

1.1 Background

With increasing population and the effects of climate change unfolding, minimizing the negative impacts of agricultural production has become of increasing interest. Current issues affecting sustainable agricultural production include excessive irrigation and overfertilization, leading to non-point source pollution when combined. Non-point source pollution is caused by excess water from irrigation which carries pollutants, such as fertilizers, into nearby streams and rivers. Additionally, excessive irrigation exacerbates soil degradation and erosion, which can negatively impact productivity. Conventional management practices lead to environmental degradation that will be made worse by climate change.

Agriculture has a rich history in Georgia, often credited with being one of the oldest and largest industries in the state. As a result, the state's economy has become reliant on agriculture, which generated $69.4 billion worth of food and fiber production in 2020 (Kane, 2020) and employs almost half of the population in the state. In 2020, there were 41,500 farms in Georgia, making up 28% of the land in the state (University of Arkansas, 2020). Agriculture will continue to be a major part of the economy in Georgia. Therefore, maintaining long-term sustainability is critical for the future of the state.

Two of the most successful crops in Georgia are cotton and peanuts, which were responsible for 10.5% of the state's value of food and fiber production in 2020 (Kane, 2020).

Cotton is frequently valued as the second largest commodity in the state of Georgia and Georgia is one of the leading cotton-producing states in the U.S., exporting $797 million in cotton in 2020 (USDA, 2021). Georgia peanut producers were responsible for growing over 50% of the nation's supply of peanuts in 2020, valued at $680 million (Kane, 2020). Peanut yield per acre in Georgia is expected to be the second-highest average on record in 2022 at 4,450 pounds per acre (Smith, 2021). Fostering sustainable production is critical for Georgia's economy.

Using conservation technologies, best management practices (BMPs) are designed to maximize resource use and minimize pollution. BMPs are developed based on regional practices to protect soil, water, and other resources to minimize environmental damages (Sharpley et al., 2006). The goal of conservation practices is to mitigate environmental damages through minimal soil disturbance, in turn increasing nutrient and water efficiency, which helps promote sustainable production practices. The most common BMPs aim to reduce soil disturbance and maximize irrigation efficiency through irrigation management, cover crops, and conservation tillage. BMPs can increase resource efficiency and minimize pollution, often without reducing farm productivity (Dickson et al., 2016; Stuart et al., 2018; Valentin et al., 2004). Additionally, with input prices increasing, rising from 80% to over 100% from November 2020 to November 2021 (Thiesse, 2021), more efficient input use can help to keep production costs at a relatively lower level. While BMPs are shown to improve environmental conditions, they can also reduce irrigation, fertilizer, and tillage costs. However, implementation of BMPs could also increase other production costs, and there are concerns as to whether yield will be affected when changing management practices. Adoption of BMPs is often met with producer hesitation due to uncertainty of profitability and feasibility of implementation.

1.2 Research Questions

BMPs can increase input efficiency and reduce part of the production costs, while requiring additional investment for implementation. The unknown impact of BMPs on costs, crop yield and ultimately farm profitability causes producers to hesitate to implement. To quantify the risk of BMP implementation for cotton and peanut production in Georgia, we investigated the variability in net returns between alternative BMP systems. The BMP systems were evaluated at three scenario levels: intensive, typical, and minimal adoption of conservation technologies. Management System 1 (MS 1) is the intensive adoption of conservation technologies and practices, including strip tillage, soil moisture sensors, and cover crops. Management System 2 (MS 2) represents typical practices of cotton and peanut producers in the region. Management System 3 (MS 3) represents the minimal adoption of conservation technologies, with producers in this category implementing conventional tillage, no irrigation management, and no cover crops. These BMP systems were developed by interviewing researchers, producers, and extension agents to represent current land-use practices in the region and updated to include conservation technologies. This project aims to answer the following research questions:

1. What is the impact of BMP bundles on cotton and peanut crop production?
2. How do agricultural BMPs affect cotton and peanut net returns?
3. What is the risk-efficient bundle of BMPs for cotton and peanut producers?

1.3 Research Objectives

This study evaluates the effect of three management practices (MS1, MS2, and MS3), with varying degrees of BMP implementation, including conservation tillage, cover crops, and irrigation management. We seek to determine the economic impact of BMPs on cotton and peanut production to provide producers with valuable information about the costs and benefits of BMP adoption using enterprise budgeting and economic simulation. Additionally, we seek to identify the risk-efficient management system for producers using stochastic efficiency with respect to a function.

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Chapter 2

Literature Review

2.1 Crop Production

Agricultural production can create a large amount of environmental degradation, with some crops requiring the application of chemicals up to 20 times per growing season (Pimentel et al., 1993). Historically, cotton and peanut crops are known to be chemically intensive in their production practices. Over the years, U.S. cotton and peanut growers were able to gradually adopt conservation practices, while making significant gains in yield and reducing the environmental impact. In 2018, in six peanut-growing states, Alabama, Florida, Georgia, North Carolina, South Carolina, and Texas, herbicides, fungicides, and insecticides were applied to 94%, 88%, and 37%, respectively, of planted peanut acres (USDA, 2018). According to the United States Department of Agriculture (USDA), fertilizer use in cotton production in the United States averaged an application rate of 95 pounds per acre in 2021 (2022). However, heavy chemical use threatens water quality and quantity and reduces the quality of planting soil, impacting crop productivity. Conventional tillage can also result in reduced soil quality, reduced productivity, and increased soil erosion. Water use has increased by 723% in Georgia from 1960 to 1995 (Gonzalez-Alvarez et al., 2006) and is expected to continue growing due to the increased population and increasing need for irrigation. These issues create long-lasting impacts on land productivity, water availability, and water quality in the surrounding areas.

BMPs are widely known to help combat environmental degradation, such as water pollution, declining soil conditions, and soil erosion, due to agricultural production. Much of the existing research on best management practices are evaluated at individual conservation techniques (Causarano et al., 2006; Dong et al., 2016; Riar et al., 2013), with limited research on a bundle of conservation techniques. The availability of literature also fails to address the risk attitudes of producers in BMP adoption (Awan et al., 2015; Zhou et al., 2021). Producers are hesitant to change management practices due to uncertainty about the effect on profitability and feasibility of implementation (Liu et al., 2018). In some cases, implementation costs of certain BMPs may outweigh the benefits for producers, which requires policy interventions such as cost-share programs to encourage more adoption. This research evaluates the effect of three management practices (MS1, MS2, and MS3) that implement different degrees of conservation techniques, including conservation tillage, cover crops, and irrigation management, on the economic performance of cotton and peanut production.

2.2 Tillage

Conventional tillage practices not only leave soil prone to erosion but can reduce the number of nutrients in the soil that is helpful for plant growth (Aziz et al., 2013; Gajda et al., 2013; Fuentes et al., 2009). The purpose of conservation tillage is to create conditions that minimize wind and water erosion, reduce energy consumption, and preserve soil and water quality (Unger & McCalla, 1980). Laufer et al. (2016) found that strip-tillage reduced runoff and soil loss by 92% and 95%, respectively, compared to conventional tillage. Current literature on the overall effect of conservation tillage on yield is inconclusive. Chen et al. (2011) found that, while soybean yield increased by 10% under no-till, corn yield decreased by 30%. Conservation tillage reduces machinery, labor, and other production costs associated with conventional tillage.

Harman et al. (1989) compared the economics of conventional till and no till in cotton production and concluded that no till provided larger annual profit in the long term due to reduced depreciation and larger yields. As input prices grow, conservation practices that maximize resources will become more profitable in the long run. Nail et al. (2007) found that reduced diesel costs from adopting conservation tillage were large enough to compensate for increased input costs associated with implementation and remained more profitable than conventional tillage.

2.3 Cover Crops

Cover crops are grown specifically to cover the soil between production periods to improve soil health, increase water infiltration, and decrease nutrient loss (Arbuckle & Roesch-McNally, 2015). Types of cover crops planted will have different environmental and farm benefits. Research performed by the USDA Agricultural Research Service rated rye, oat, and barley as ‘very good’ at nitrogen scavenging, lespedeza was characterized as useful for reducing soil erosion, and mustard is characterized as an efficient weed suppressor (Liebig & Johnson, 2019). Cover crops bring benefits internal to the farm as well as benefits external to the farm. Wyland et al. (1996) studied the effect of rye cover crops on irrigated broccoli and found that they reduced nitrate leaching by more than 70%. While the benefits of cover crops are widely known, the additional planting and seed costs deter implementation. A three-year cover crop study performed on cotton production in the Texas High Plains, compared gross margins for no till with rye and mixed cover and conventional tillage, and found gross margin was largest for no till with mixed cover in year one and then conventional tillage dominated (Lewis et al., 2018). The use of cover crops has also been shown to improve soil quality and increase soil organic matter, which helps to reduce the need for fertilizer. Fan et al. found that using cover crops in cotton production increased the probability of positive net returns, and producers with all risk attitudes preferred some combination of no-till and cover crops (2020). Profitability and benefits of cover crops vary based on location, type of cover, and tillage, which will affect producers' decision to adopt them.

2.4 Irrigation

Excessive irrigation not only threatens water quantity but quality. Soil, chemicals, and other particles are carried into nearby streams and rivers by excess irrigation. Gilliom (2007) found that in agricultural areas in the U.S., pesticides contaminated stream water 97% of the time and groundwater 61% of the time. Not only does the presence of chemicals in this magnitude affect aquatic-life, but there are also potentially hazardous effects to human health. Irrigation management aims to optimize water use in farming to reduce application amounts and, in turn, reduce agricultural runoff (Saccon, 2018). Irrigation management addresses the timing or scheduling of irrigation, reducing application amounts, and in turn, increasing irrigation efficiency and reducing agricultural runoff (Saccon, 2018). Irrigation management has the potential to increase farm profitability, but up-front costs can be high. Spencer et al. (2019) found that irrigation management tools, such as soil moisture sensors, surge flow irrigation, and irrigation scheduling, decreased water use and increased yield and had more favorable net returns than conventional irrigation methods.

2.5 Soil and Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) is a software designed to simulate the effect of location, weather, and management practices on crop production and environmental impacts. There are vast input data options for SWAT, depending on the desired simulation results, but required inputs include information about: watershed, precipitation, soil, climate, groundwater, and management practices (Neitsch et al., 2002). SWAT is a physically-based, semi-distributed model, which can simulate the effect of conservation practices, such as irrigation management, conservation tillage, fertilizer application and timing, and cover crops. The farm-scale impact of BMPs can be quantified by altering the management practices during the input stage of SWAT (Karki et al., 2020). Once the SWAT model has been set up, calibrated, and model confirmed, the model can sufficiently simulate nutrient runoff, soil moisture, and other environmental factors. There have been many projects that use the SWAT model to evaluate the effect of alternative management practices on crop yield, net returns, water quality and quantity, and other environmental factors (Bracmort et al., 2006; Maski et al., 2008; Motsinger et al., 2016; Parajuli et al., 2013; Sood & Ritter, 2010; Uribe et al., 2018 Yang et al., 2012; Xu et al., 2018).

2.6 Enterprise Budgeting and Economic Simulation

Best management practices have the potential to increase resource efficiency, but the adoption costs may outweigh the benefits. The enterprise budget is one of the most effective resources when determining farm profitability and productivity. Enterprise budgets are often called the building blocks of farm plans because of how critical they are to the success of the farm. Enterprise budgeting is done for an individual farm enterprise and allows farmers to assess variable costs, fixed costs, and returns per acre, which are key in determining profit margins (Langemeier, 2015; Fonsah et al., 2020).

Enterprise budgets can be used to simulate possible yield, costs, and profit data based on historical values of certain variables. There are several types of simulations that can be performed based on data and the number of observations. One of the most common simulation methods is Monte Carlo Simulation, which is a method of random sampling that samples from a defined probability distribution. The Monte Carlo method generally follows three steps, which are to: model the data as a probability density function (PDF), sample repeatedly from the PDF, then evaluate the desired variables (Harrison, 2010). When there are a large number of samples, the Monte Carlo samples will recreate the defined distribution. When there are a small number of samples, Monte Carlo simulation could cause clustering, which leads Latin Hypercube Sampling to be the more accurate method. Latin Hypercube (McKay et al., 1979) is a type of Monte Carlo sampling that divides the distribution into N intervals and samples once from each interval (Palisade, 2018). This stratification leads Latin Hypercube Sampling to converge to the distribution faster than Monte Carlo. Gibbons et al. (2006) used the Monte Carlo method to simulate 1,000 draws to model uncertainty in total greenhouse gas emissions for cattle farming and examine the optimal method to reduce emissions.

2.7 Risk

Different producers perceive a certain situation as having different amounts of risk, this perception is referred to as their risk attitude. Risk attitudes can be classified into three categories: risk-averse, risk-neutral, and risk-seeking and determine the shape of a producer’s utility function. Beginning with research performed by Von Neumann and Morgenstern (1953), Expected Utility Theory (EUT) states that, in the face of uncertainty, a decision-maker will choose an outcome that maximizes their expected utility. The Von Neumann-Morgenstern utility function can be expressed as $U = U(w)$, where w represents wealth. Certain qualities may influence some producers’ choice to change management practice over others. Though, degree of risk aversion varies, the majority of studies show that farmers are risk-averse (Menapace et al., 2013; Kahan, 2008). Using EUT, Arrow (1965) and Pratt (1964) developed measures of risk that explain how wealth changes a decision-makers risk preference. The Arrow-Pratt measures of risk aversion has been widely used to evaluate choices when the decision-maker is faced with uncertainty (Babcock and Shogren, 1995; Campbell et al., 2021; Cochran, Robinson, and Lodwick, 1985; Cochran et al., 1985; Simtowe, 2006). Two measures of risk aversion developed by Arrow and Pratt are the relative risk aversion coefficient (RRAC) and the absolute risk aversion coefficient (ARAC). Relative risk aversion measures a decision-makers willingness to take-on risk as a percentage of their wealth, while absolute risk aversion is measured in dollar terms. The relative risk aversion coefficient (r_r) and absolute risk aversion coefficient (r_a) are calculated by taking the first (U') and second (U'') derivatives of utility using the following formulas:

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

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

Relative risk aversion can be transformed into absolute by dividing by wealth, illustrated in the following formula:

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

Building on Arrow and Pratt's theory, Anderson and Dillon (1992) determined the RRAC to range from 0 to 4.0, which represents attitudes from risk neutral to extremely risk averse, respectively.

2.8 Stochastic Efficiency with Respect to a Function

Stochastic Efficiency with Respect to a Function (SERF) is a utility-based method that uses EUT and the Arrow-Pratt risk aversion coefficient to rank risky outcomes (Hardaker et al., 2004). Outcomes are ranked using certainty equivalents (CEs) for a specified range of risk attitudes. A CE is the certain sum that results in the same utility as the expected utility of the risky outcome, causing the decision maker to be indifferent between the two choices (Hardaker et al., 2004; Richardson et al., 2008). CEs are calculated for each possible outcome over a range of risk aversion coefficients (r) by using the inverse of the utility function using the following formula:

$$U(CE, r) = EU(w, r) = \sum_{i=1}^{m} U(w_i, r) P_{i,} \quad (4)$$

$$r_1 \leq r \leq r_2$$

$$CE(w, r) = U^{-1}(w, r) \quad (5)$$

Ample research has used SERF to evaluate the impact of conservation tillage, cover crops, and irrigation management (Adusumilli et al., 2020; Boyer et al., 2018; Grove et al., 2006; Fan et al., 2020; Hignight et al., 2010; Leiva & Skees, 2008; Watkins et al., 2010; Williams et al., 2015). At a certain risk aversion coefficient subtracting the CEs of alternative practices from producer's current practice yields the utility-weighted risk premium (RP). A positive RP indicates the gains to a producer if they were to switch from their current practice to a dominant alternative. This indicates producers' willingness to adopt the alternative practices. Negative RPs are the losses to a producer if they were to switch from their current practice to a less preferred alternative practice. The absolute value of a negative RP is the dollar value that would encourage a producer to change from their current choice to a less preferred, riskier alternative. 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):

$$RP_{j,l,r} = CE_{j,r} - CE_{l,r} \tag{6}$$

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Chapter 3

Farm-Scale Economic Analysis of Cotton Best Management Practices

Judd, Rachel M. To be submitted to *Agronomy Journal.*

3.1 Abstract

Fostering sustainable agricultural practices has become of increasing importance in the face of a growing population and climate change. Cotton is one of the largest crops in Georgia, consistently ranking first by value among row and forage crops statewide. Best management practices (BMPs) promote more efficient resource-use than traditional practices, helping to reduce environmental impacts and combat rising input costs. Producer adoption of BMPs is met with hesitation due to the uncertain impact on yields, costs, and profitability. Current literature evaluates the impact of conservation technologies individually, failing to address the joint effects of BMP bundles. Literature also does not consider the risk attitudes of producers. The risk associated with alternative BMP bundles in this research was quantified by evaluating the variability in net returns. BMP bundles were created using data collected from extension agents and producers at three scenario levels: minimal, typical, and intensive adoption of conservation technologies and practices. Enterprise budgets were created at each scenario level, including farm-scale production costs for BMPs. Simetar software was used to simulate net returns for each scenario level and determine the feasibility of BMP adoption. The risk-efficient management system for cotton production was determined using Stochastic Efficiency with Respect to a Function (SERF), which uses certainty equivalents to rank risky alternatives. Results indicate that conservation technologies decreased yield and increased production costs, negatively impacting net returns. The risk-efficient management practice was determined to be

the minimal adoption of conservation technologies. Results can inform cotton producers about regional adoption of BMPs.

3.2 Cotton Production

Cotton producers have been suffering from soil erosion due to the small amount of residue left after harvesting, which can negatively impact yields (Boyer et al., 2018; Nyakatawa et al., 2001). Soil erosion coupled with over irrigation and fertilization in agricultural production can lead to nutrient leaching in groundwater. Combined with chemicals applied during agricultural production, such as fertilizers, herbicides, and insecticides, these factors can cause environmental damages, deteriorate soil quality, and impact yields. Conservation practices for agricultural production can help reduce environmental degradation and increase resource efficiency to help combat rising input prices.

Conservation tillage includes no-till, minimal till, and strip till, creating conditions that minimize soil erosion (Busari et al., 2015; Pierce, 1998; Unger & McCalla, 1980;), improve soil health, and improve yields for certain crops (Busari et al., 2015; Govaerts et al., 2005; Harman et al., 1989). Fewer tillage trips that come with conservation tillage can improve profitability through reduced machinery, fuel, and labor costs (Harman et al., 1989; Liu & Duffy, 1996; Nail et al., 2007). Cover crops are grown between production periods to cover the soil, rather than for harvesting. Cover crops are effective weed suppressors and nitrogen scavengers, reducing the need for chemical applications (Liebig & Johnson, 2019). Combined implementation of conservation tillage and cover crops also help to improve infiltration, increase irrigation efficiency, and reduce non-point source (NPS) pollution (Ali et al., 2017; Arriaga & Balkcom, 2005; DeLaune et al., 2020; Frye & Blevins, 1989). Additionally, conservation tillage and cover crops have been shown to improve soil quality through improved chemical, biological, and physical characteristics (Adetunji et al., 2020; Dabney et al., 2001; Lal & Kimble, 1997; Pierce, 1998; Reicosky & Forcella 1998).

Irrigation management, such as irrigation scheduling, optimizes water-use, reducing the need to irrigate and increasing the availability of water resources. Some studies show that irrigation scheduling can increase yields in certain crops (Chauhan et al., 2013; El Afandi et al., 2010; Wanjura et al., 2002). While irrigation management can potentially decrease operating costs by reducing irrigation amounts, but implementation costs can be high.

Among row and forage crops cotton ranks number one by value in Georgia and second largest by value in the United States (Kane, 2020). In 2020 cotton production accounted for 6% of food and fiber production in Georgia, generating over $720 million for the state (Kane, 2020). Georgia has a rich history with cotton, being the first colony to produce the crop commercially. Cotton production to be an integral part of Georgia’s economy. The central role of cotton in Georgia’s economy will continue, but limited resources and declining environmental conditions can increase costs and reduce profits.

While BMPs have been shown to increase production efficiency and improve environmental conditions, the producers hesitate to adopt due to the impact on yields and farm profits. This study aims to determine the impact of BMP bundles on cotton yields and net returns. We also aim to identify the risk efficient bundle for cotton producers.

3.3 Data and Methods

3.3.1 Management Practices and Soil and Water Assessment Tool

Three best management practice (BMP) bundles (Table 1) were evaluated in this research, each with varying degrees of conservation technologies. The management systems were created based on interviews with producers and local extension agents. Management System 1 (MS 1) represents the most intensive adoption of conservation practices. Producers in this category implement strip tillage, soil moisture sensors, soil and tissue tests, and cover crops. This management system applies the smallest amount of fertilizer of the three systems and is most likely to result in the least amount of nitrate leaching. Management System 2 (MS 2) represents practices that are typical of producers in the area, implementing conventional tillage, soil tests, no cover crops, and applying the second largest amount of fertilizer of each of the management systems. Producers in Management System 3 (MS 3) implement the least amount of conservation technologies. MS 3 consists of conventional tillage, no soil or tissue tests, no cover crops, and the largest amount of fertilizer applications. MS 1 is the most sustainable system with the most efficient resource-use. MS 3 is the least sustainable and most likely to result in the greatest nitrogen leaching.

Table 1. Best Management Practice Bundles for Cotton Production

Best Management Practices	**Management System 1**	**Management System 2**	**Management System 3**
Tillage	Strip Tillage	Conventional Tillage	Conventional Tillage
Irrigation Equipment	Soil Moisture Sensors (SMS)	None	None
Irrigation Management	Monitor SMS	UGA Checkbook	Minimum 1 ac-in per week
Irrigation Efficiency	85% efficient	80% efficient	80% efficient
Fertilizer Equipment	Custom spread lime, P&K; Side Dress N	Custom Spread Lime, P&K; Side Dress N	Custom Spread Lime, Disc P&K, Side Dress N
Custom Spreading	Grid Sample + Variable Lime, P&K	Lime, P&K	Lime
Soil Fertility Management	Soil + Tissue Test	Soil Test	None
Fertilizer	Trip 1: 1/3 ton lime, 20 lb N Starter Fertilizer Trip 2: 30 lb N Side Dress Trip 3: 30 lb N Side Dress Trip 4: 30 lb N Side Dress	Trip 1: 1/3 ton Lime, 2 tons Chicken Litter Trip 2: 70 lb N Side Dress	Trip 1: 1/3 ton lime, 2 tons Chicken Litter Trip 2: 90 lb N Side Dress Trip 3: 30 lb N After Planting
Fertilizer Application	Custom spread lime, P&K, Side Dress N	Custom Spread Lime, P&K Side Dress N	Custom Spread Lime, Disc P&K Side Dress N
Cover Crops	Rye, no bailing	None	None

The Soil & Water Assessment Tool (SWAT) is a river basin-scale model that measures the impact of management practices, climate change, and land use on crop production (Neitsch et al., 2019). Common applications of SWAT include evaluating soil erosion, pollution control, and water use. Common SWAT inputs include land-use, elevation, climate, soil type, and management actions, including crop rotations, tillage, and cover crops. The SWAT process involves model setup, model calibration, and model confirmation. Once these three steps are completed SWAT is believed to sufficiently simulate runoff, soil moisture, and other environmental factors influenced by different management practices. For this study, 27 years of historic temperature and precipitation from 1990 to 2016 were input into the SWAT model along with characteristics of each management system. The resulting outputs from SWAT were used for further economic analysis as the variables in this study, including annual yield totals, irrigation amounts, and nitrate loss for each management system from 1990 to 2016.

3.3.2 Enterprise Budgets and Economic Simulations

Enterprise budgets were developed to estimate the production costs for each of the three scenario levels: intensive, typical, and minimal adoption of conservation technologies to capture the costs of implementing BMP bundles. Enterprise budgets were created based on the University of Georgia's 2021 Cotton Extension Budgets (Zhou et al., 2021) and updated based on interviews with extension agents and cotton producers to include farm-scale production costs for best management practices. Irrigation budgets were integrated into the enterprise budgets using the University of Georgia's 2021 Center Pivot, 160 Acres Electric irrigation budget (Bhattarai et al., 2021) to incorporate the different irrigation costs associated with each management system. Net returns were calculated from enterprise budgets as:

$$NetReturns_{it} = (LintYield_{it}) \times (Lint\ Price_t) + (Seed\ Yield_{it}) \times (Seed\ Price_t) - Nitrogen\ Variable\ Costs_{it} - Other\ Fertilizer\ Variable\ Costs_{it} - Irrigation\ Variable\ Costs_{it} - Other\ \ Fixed\ Costs_{it} - Other\ Variable\ Costs_{it} \qquad (7)$$

Where *i* denotes management system (MS 1, MS 2, and MS 3) and *t* represents the year.

The University of Georgia Extension Budget calculates cotton seed yield from lint yield using the assumption that 50% of yield is seed, 40% is lint, and 10% is trash. Seed yield was calculated from SWAT yield using these percentages. We collected historic annual lint price and seed price from the United States Department of Agriculture National Agricultural Statistics Service from 1990 to 2016 (USDA NASS, 2021a). Historical nitrogen prices were obtained by using nitrogen prices from the 2021 Cotton Extension Budgets and annual nitrogen price index data collected from USDA NASS (2021b). Nitrogen price index values were used to convert to the 2021 nitrogen price to historical nitrogen prices at nominal values using the following formula:

$$Nominal\ Nitrogen\ Price_t = Nitrogen\ Price_{2021} \times \frac{Nitrogen\ Price\ Index_t}{Nitrogen\ Price\ Index_{2021}} \qquad (8)$$

Cotton Enterprise Budgets were created based on 2021 University of Georgia Extension Budgets; therefore, all prices were converted to 2021 prices. The Personal Consumption Expenditures (PCE) Price Index was used to convert lint price, seed price, and nitrogen price to 2021 values (U.S. Bureau of Economic Analysis, 1959).

$$Real\ Price_t = \frac{PCE_{2021}}{PCE_t} \times nominal\ price_t \qquad (9)$$

To capture the impact of weather conditions and management practices on net returns, 500 draws of net returns were simulated using the Latin Hypercube method of sampling. For each draw of net return, nitrogen price, cotton lint price, and cotton seed price, together with SWAT simulated cotton yield and the amount of in-season irrigation, were empirically defined using a univariate empirical simulation. This function uses the distribution of observed data to assign probabilities and distributions to the simulated data (Richardson et al., 2008). A multivariate distribution between cotton prices and yield would simulate the impact of implementing BMP bundles on a larger scale, such as regionally or statewide. We used a univariate empirical simulation between cotton prices and yield, rather than multivariate empirical to assess the impact of BMP bundles at the farm-scale. 500 draws of net returns were simulated for each management system using the Latin Hypercube method of sampling.

To ensure the most accurate simulated variables, two methods of sampling were used: Latin Hypercube and Monte Carlo. Each method was used to simulate cotton yields then compared to the SWAT simulated yields using the compare two series function in Simulation and Econometrics to Analyze Risk (SIMETAR) (Richardson et al., 2008). This function uses the Student’s T to test means and F-Test for variance. Both of the methods of simulation failed to reject the null hypothesis of equal means and variance between the two. However, the Latin

Hypercube method had more favorable critical values and p-values, so this method was used for simulations of all variables.

Table 2. Hypothesis Test Results for Latin Hypercube and Monte Carlo Simulation Method

Test Method	Test Value	Critical Value	P-Value	Test Result
Latin Hypercube Simulation Method				
2 Sample T-Test	0.07	2.37	0.943	Fail to Reject H0 that Means are Equal
F Test	1.25	1.52	0.186	Fail to Reject the H0 that the Variances are Equal
Monte Carlo Simulation Method				
2 Sample T-Test	0.31	2.37	0.759	Fail to Reject H0 that Means are Equal
F Test	1.28	1.52	0.163	Fail to Reject the H0 that the Variances are Equal

3.3.3 Stoplight Chart Analysis

The distribution of the simulated net returns can be better understood through a Stoplight Chart Analysis. The Stoplight Chart Analysis is a SIMETAR function that calculates the probability that risky alternatives will result in values below a lower target value, above an upper target value, and in between the defined values (Richardson et al., 2008). The most commonly defined bounds are the 25th percentile for the lower bound and the 75th percentile for the upper bound. Bounds were set as values of simulated net returns across all management systems.

3.3.4 Stochastic Efficiency with Respect to a Function (SERF)

Stochastic Efficiency with Respect to a Function (SERF) was used to identify the risk-efficient management system for a range of specified risk attitudes (Hardaker et al., 2004). Ample studies have used SERF to rank alternative production practices (Acharya et al., 2019; Adusumilli et al., 2020; Archer & Reicosky, 2009; Fan et al., 2020; Fathelrahman et al., 2011; Wang et al., 2020). This method calculates certainty equivalents (CEs) to rank risky alternatives.

A CE is the guaranteed sum of money that would make the producer indifferent between the net returns of their current practice and the guaranteed sum. CE's are the risk-adjusted net return per hectare for each management system, which is calculated using the formula:

$$CE(w, r) = U^{-1}(w, r) \tag{10}$$

where w represents wealth, $U(w)$ is the specified utility function, and r is the risk aversion coefficient. For this research we specified a negative exponential utility function, which indicates that the level of wealth a producer has is independent of their risk aversion level. The negative exponential utility function takes the following form:

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

The negative exponential utility function indicates a producer has a constant absolute risk aversion (r_a) (Babcock et al., 1993; Pendell et al., 2007; Adusumilli, 2020). Absolute risk aversion coefficients (ARACs) are calculated by dividing relative risk aversion coefficients, which range from risk-neutral (0) to extremely risk-averse (4), by wealth. In this study wealth was calculated as the average of simulated net returns of $1,069.47 per hectare across all management systems. Thus, the ARACs range from 0 to 0.0037.

Risk Premiums are the gains or losses to a producer if they were to switch from their current practice to an alternative practice. If the RP is negative, a producer will realize a loss if they were to switch. A positive RP indicates gains to a producer if they were to switch practices. For example, if a producer is currently implementing MS 2, the RP for a producer to switch to MS 1 is calculated as:

$$RP_{1,2,r_i} = CE_{1,r_i(w)} - CE_{2,r_i(w)} \tag{12}$$

3.4 Results

3.4.1 Impact of Conservation Technologies

The SWAT simulated data reflects the impact of conservation practices on yields, irrigation amounts, and nitrate leaching as shown in Table 3.

Yield

The data summarized in Table 3 shows that conservation technologies negatively impacted yield. MS 1 resulted in reduced yields from typical production practices of MS 2, by an average of 110.92 kilograms per hectare. Yield amounts for MS 2 and MS 3 are not significantly different, with MS 3 averaging only 52.27 kilograms per hectare more than MS 2. However, yield stability was increased through conservation technologies, with MS 1 having the smallest standard deviation and MS 3 having the highest. Differences in yield amounts are likely due to applications of poultry litter applied before planting in MS 2 and MS 3, as well as increased fertilizer applications and irrigation amounts for MS 3.

Irrigation

The irrigation management technologies were successful at increasing irrigation efficiency and reducing irrigation amounts. Soil moisture sensors were successful in reducing irrigation amounts, with the average irrigation during the season for MS 1 being 17.78 to 131.57 mm less than MS 2 and MS 3, respectively. While implementation of the soil moisture sensors increased production costs, they effectively reduced irrigation costs and use of water resources. The UGA Checkbook method of irrigation used in MS 2 had a higher average value than MS 1. However, the variability was the smallest in MS 2, with a standard deviation of 44.70. MS 3 had the highest overall irrigation application, averaging 250.19 mm. The irrigation management technologies were successful at increasing irrigation efficiency and reducing irrigation amounts.

On average, the using of soil moisture sensors reduced the amounts of irrigation for MS 1 by 13% and 53% compared with MS 2 and MS 3, respectively.

Nitrate Leaching

Conservation practices reduced nitrate loss, as nitrate loss in MS 3 was highest and in MS 1 was lowest, with MS 2 in between. Average nitrogen leaching in MS 1 was significantly less than that of MS 2 and MS 3, averaging 4.17 kilograms per hectare per year. The larger fertilizer applications and irrigation amounts in MS 3 lead to the most amount of nitrate leached in MS 3, averaging 76.99 kilograms per hectare per year. The average amount of nitrogen leaching in MS 2 fell in between the averages of MS 1 and MS 3, at 55.48 kilograms per hectare per year. Minimum nitrate leaching in MS 1 was due to fertilizer and irrigation efficiency, cover crops, and strip tillage implemented in MS 1.

Table 3. Summary of Statistics for SWAT Generated Cotton Data

	Average	Minimum	Maximum	Standard Deviation
Yield (kg/ha)				
Management System 1	1,641.57	1,128.99	2,082.66	263.80
Management System 2	1,752.49	1,191.01	2,260.06	295.24
Management System 3	1,804.76	1,201.63	2,332.21	331.20
Irrigation (mm)				
Management System 1	118.62	19.05	247.65	50.04
Management System 2	136.40	36.07	203.2	44.70
Management System 3	250.19	136.40	337.57	59.94
Nitrate Leached (kg/ha/yr)				
Management System 1	4.17	0	17.33	5.30
Management System 2	55.48	0	277.88	57.45
Management System 3	76.99	3.56	271.36	61.34

3.4.2 Impact on Costs and Net Returns

Costs per hectare for each management system were evaluated using static prices and are detailed in Figure 1, complete enterprise budgets are included in the appendix. While conservation technologies increased costs per hectare from typical production practices (MS 2), MS 3 resulted in the highest costs of $2,483.37 per hectare. General variable, general fixed, fertilizer variable, and irrigation variable costs were highest for MS 3. MS 1 had the largest best management practice fixed and variable costs, which are due to the pre-harvest machinery costs associated with more fertilizer trips than the other management systems. The smallest costs per hectare were under MS 2, ranging from $30.16 to $40.66 per hectare less than MS 2 and MS 3, respectively.

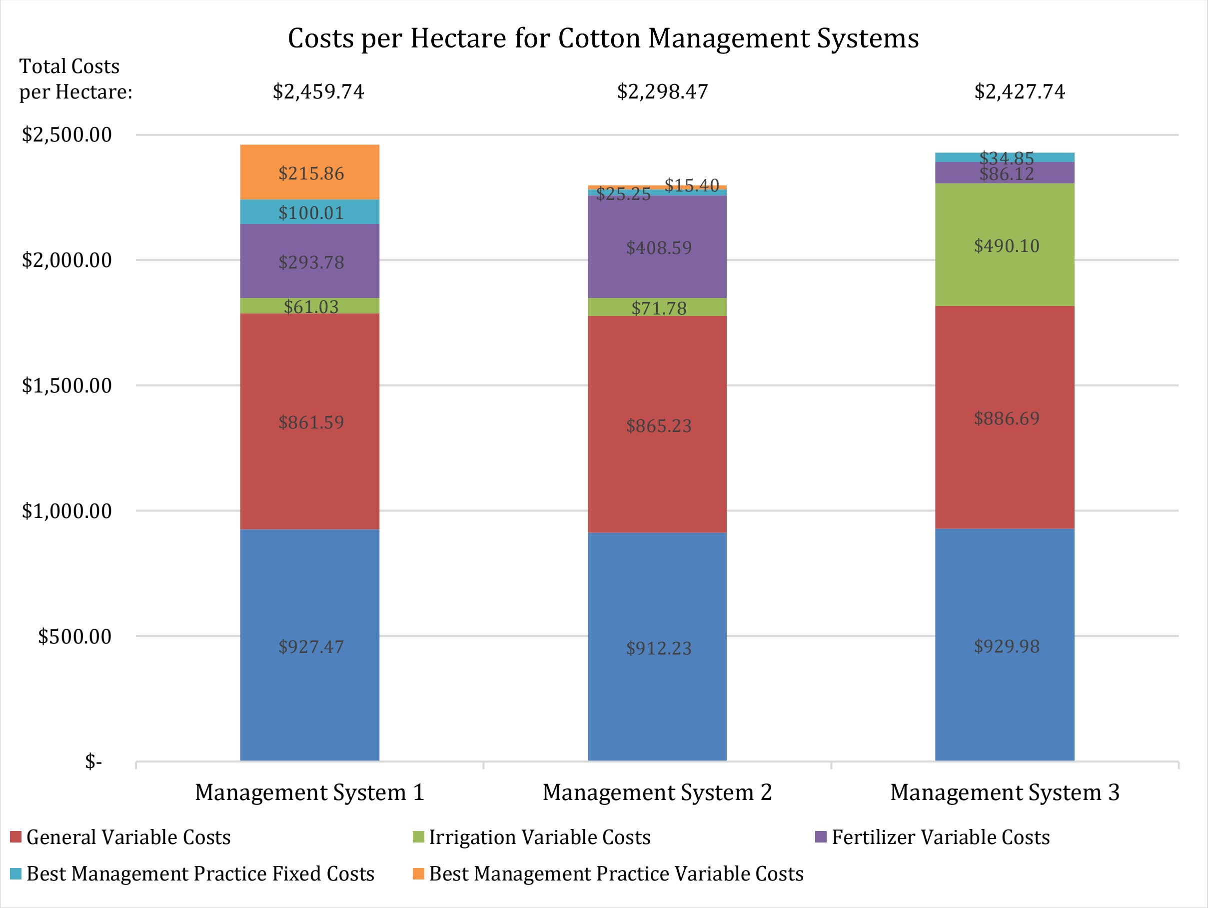

Figure 1. Cotton Cost per Hectare by Management System ($/ha)

Simulated net returns for the management systems are summarized in Table 4. The combination of reduced yields and high costs for MS 1 led to the possibility of the largest losses and smallest profits. MS 1 averaged $375.22 to $406.44 per hectare less than MS 3 and MS 2, respectively. Net returns for MS 2 averaged $1,215.10 per hectare, the largest of all three management systems. MS 3 offered the second highest net returns, averaging $1,183.88 per hectare, only slightly higher than the average net returns under MS 1. The standard deviation in MS 3 was the highest, which indicates yields under this system are the least stable.

Table 4. Summary of Simulated Cotton Net Returns per hectare

	Average	Minimum	Maximum	Standard Deviation
Net Returns ($/ha)				
Management System 1	$808.66	($807.47)	$3,415.22	$813.56
Management System 2	$1,215.10	($585.95)	$3,978.06	$906.33
Management System 3	$1,183.88	($751.31)	$4,155.70	$920.45

3.4.3 Stoplight Analysis

The Stoplight chart depicts the probability of net returns per hectare in each management system being less than $411.08 (25th percentile), exceeding $1,662.07 (75th percentile), and falling in between these values. Results of the Stoplight analysis are shown in Figure 2. The probability of MS 3 exceeding the upper cutoff value is 30%, the largest of all three systems. MS 2 is only slightly behind, with a 29% chance of the net returns exceeding the upper value and the smallest probability of 18% of falling below the lower cutoff value. MS 2 has the largest probability at 52% of being between the upper and lower cutoff values, followed by MS 1 with 50%, and MS 3 with 47%. A larger probability in between the upper and lower cutoff values indicates that the system is more stable. The stoplight chart, however, only calculates the probability of net returns for each system falling above or below certain values, but not the magnitude of the net returns. Therefore, the risk associated with each system is not considered.

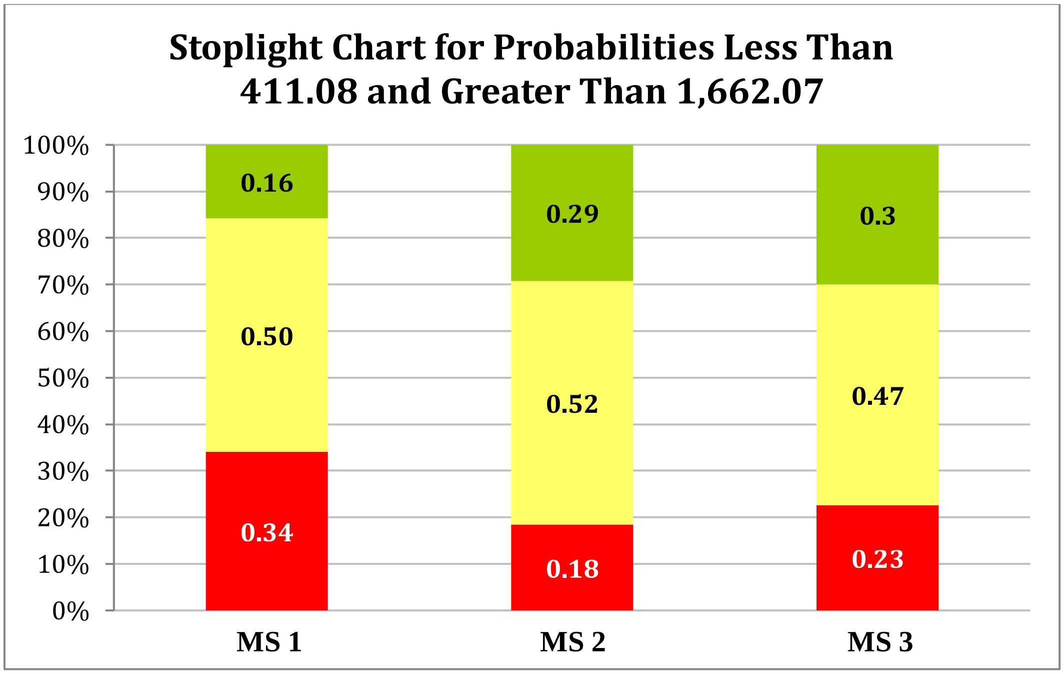

Figure 2. Stoplight Chart for Simulated Net Returns for Cotton Production per Hectare

3.4.4 Stochastic Efficiency with Respect to a Function

Certainty Equivalents

A negative exponential utility function was used to calculate certainty equivalents (CEs). A chart of the CEs across specified ARACs is depicted in Figure 2. As risk aversion increases, CEs decrease. CEs for MS 2 are the highest, ranging from $357.27 to $1,215.10 per hectare, meaning it is the most preferred by cotton producers. MS 1 remains the least preferred by producers across all levels of risk aversion, with CEs ranging from $44.38 per hectare for extremely risk averse producers to $808.66 per hectare for risk neutral producers. While preference for MS 2 and MS 3 begin as closely preferred, as risk aversion grows producer’s preference for MS 2 over MS 3 increases.

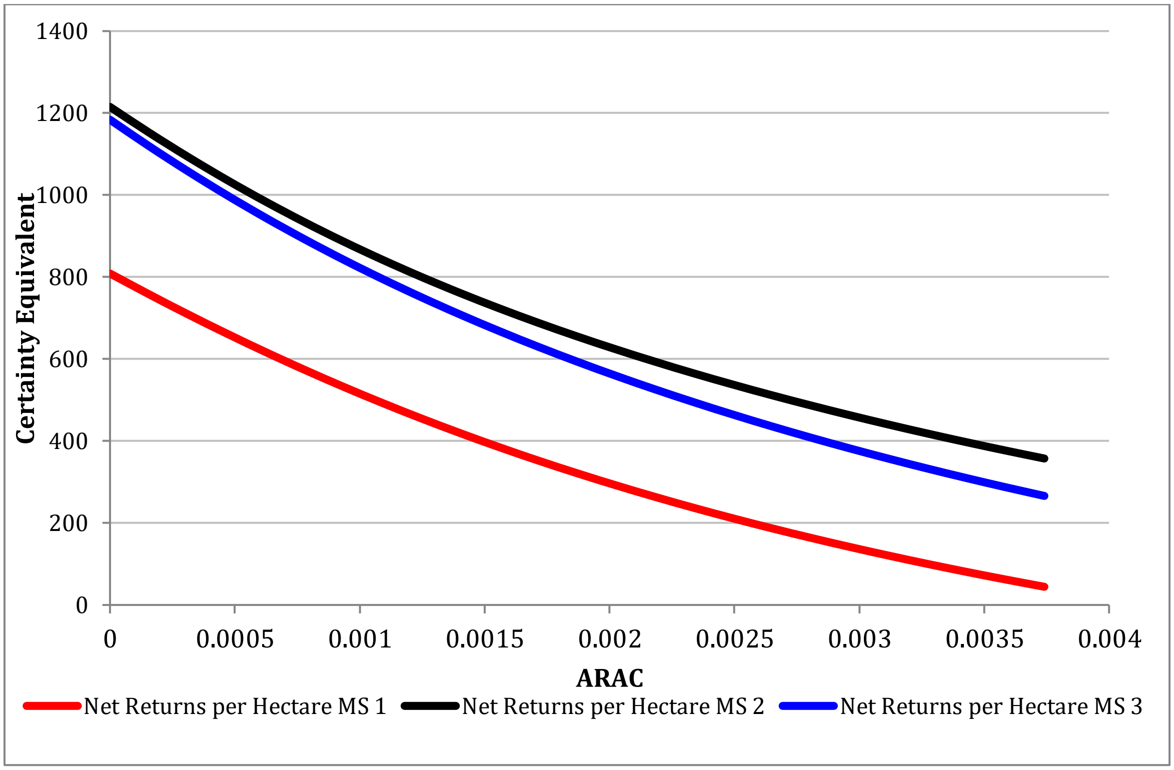

Figure 3. Stochastic Efficiency with Respect to a Function under Negative Exponential Utility for Cotton Production

Risk Premiums

Calculating risk premiums requires specifying a base management system. Producer adoption of MS 1, the intensive implementation of conservation technologies, is encouraged, so MS 1 was set as the base system. Figure 3 illustrates a graph of utility weighted risk premiums (RPs) across specified ARACs. Risk premiums for MS 2 and MS 3 are negative, indicating MS 1 is least preferred by cotton producers at all ARACs. If producers were implementing MS 2, a payment of $312.90 to $406.44 per hectare, depending on their risk attitude, would be required to prompt a switch to MS 1. To prompt producers who are currently implementing MS 3 to adopt MS 1 a payment of $221.66 to $375.22 per hectare would be required, depending on the producers' risk attitude. Risk premiums at each ARAC are depicted in Table 5.

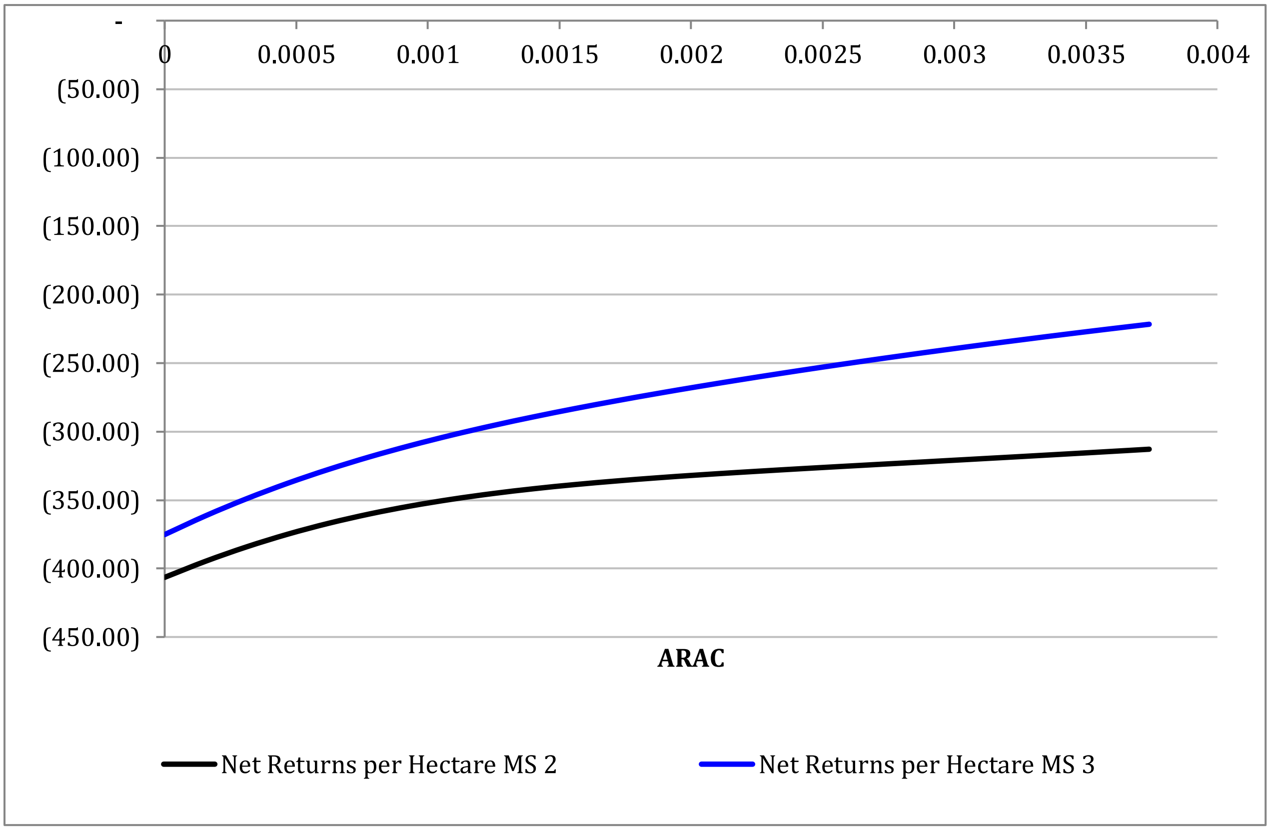

Figure 4. Negative Exponential Utility Weighted Risk Premiums Relative to Net Returns per Hectare for Cotton Management System 1

Table 5. Utility Weighted Risk Premiums for Cotton Best Management Bundles Relative to MS 1

	Risk Neutral	Somewhat Risk Averse	Rather Risk Averse	Very Risk Averse	Extremely Risk Averse
	0.00	0.00094	0.0019	0.0028	0.0037
Risk Premiums for Management System 1 ($/ha)					
Management System 2	($406.44)	($354.33)	($333.70)	($322.99)	($312.90)
Management System 3	($375.22)	($310.13)	($272.27)	($244.52)	($221.66)

3.5 Conclusion

This project evaluated the economic impact of conservation technologies and sought to determine the risk-efficient management practice for cotton production. We found that implementing conservation practices, such as strip tillage, soil moisture sensors, and cover crops, had negative impacts on yields in cotton production, but increased irrigation efficiency. Enterprise budgeting showed that conservation technologies successfully reduced input costs, such as fertilizer and irrigation costs, but increased costs associated with implementing conservation technologies. The decrease in input costs were not large enough to compensate for the increased implementation costs and reduced yields associated with Management System 1.

When accounting for producers' risk attitudes, we found that Management System 2 was most preferred for cotton producers. Management System 1 was the least preferred by producers with all risk attitudes. To prompt adoption of Management System 1, producers currently implementing Management System 2 require a payment ranging from $313 to $406 per hectare.

Producers currently implementing Management System 3 would require a payment of $222 to $375 per hectare to switch to Management System 1.

Higher input prices, such as fertilizers, will cause the risk associated with the systems that have the larger input costs to increase. This will cause the costs of Management System 1 and Management System 2 to increase at a slower rate than that of Management System 3 and Management System 3 costs will increase rapidly. As input prices grow, risk premiums associated with Management Systems 1 and 2 will also likely decrease, making these systems more desirable for producers.

Long term effects of Management System 3 will likely deplete soil quality, which will negatively impact yield and result in the need for more chemicals. Producers who adopt conservation practices will see an increase in yield, due to more soil organic matter.

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Chapter 4

Farm-Scale Economic Analysis of Peanut Best Management Practices[1]

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[1] Judd, Rachel M. To be submitted to *Agronomy Journal*.

4.1 Abstract

Georgia is the largest producer of peanuts in the United States. Sustainable resource-use and management brings environmental benefits but can also help producers to keep input costs low. Best management practices (BMPs) optimize resource-use, but producers are hesitant to adopt due to the unknown impacts on yields and farm profitability. Current literature on BMPs evaluate practices individually, failing to address the joint effects of BMP implementation for peanut production. This research seeks to quantify the economic impact of BMP bundles on peanut production and determine the risk efficient bundle. BMP bundles were evaluated using data collected from extension agents and peanut producers at three scenario levels: intensive, typical, and minimal adoption of conservation technologies. Enterprise budgets were created at each scenario level, including farm-scale production costs for BMPs. The modeling software Simetar was used to simulate net returns for each BMP system and evaluate the feasibility of adoption. Stochastic Efficiency with Respect to a Function (SERF) was used to rank certainty equivalents at each level of specified risk aversion and identify with risk efficient system. We found that while BMP bundles reduced yields, they effectively reduced costs per hectare. Peanut producers at all levels of risk aversion preferred the typical implementation of BMP systems. Results can inform regional adoption of BMPs by peanut producers.

4.2 Peanut Production

Georgia is a significant peanut producer in the United States, supplying over 50% of the nation’s crop in 2020 (Kane, 2020). According to the University of Georgia Farm-Gate Value Report (Stubbs, 2020), peanut production comprised over 5% of Georgia’s total farm-gate value, at over $663 million, in 2018. With climate change and increasing populations impacting food security, peanut demand will increase due to their high protein content (Singh and Singh, 1991). Efficient peanut production will be critical to meet increasing demand.

While peanut producers typically see profits (Monfort, 2022), rising input costs lead to reduced profit margins. Additionally, traditional peanut production practices are management and resource intensive, increasing fuel, labor, input, and other farm costs, which impact farm profitability (Wright et al., 1969). Best management practices (BMPs) have been shown to reduce irrigation, fertilizer, and tillage costs, often without reducing farm productivity.

Critical factors affecting peanut production include climate, soil conditions, fertilizer, pest and weed control, and irrigation (Davidson et al., 1990; Lamb et al., 1997; Monfort, 2022; Wright et al., 1986). Soil erosion depletes soil quality, negatively impacting yields. Minimal till, strip till, and no till are types of conservation tillage which helps to reduce soil erosion. Conservation tillage reduces tillage trips and has shown to lower operating expenses, decreasing machinery, fuel, labor, and other associated production expenses (Faircloth & Rowland, 2006; Harman et al., 1989; Nail et al., 2007).

Cover crops are those grown to cover the soil between planting periods. Type of cover crops offer different benefits such as weed and pest suppression, nitrogen scavenging, improving water infiltration, and reducing erosion (Arbuckle & Roesch-McNally, 2015; Liebig & Johnson, 2019). Research shows that cover crops and conservation tillage improve soil health, improving biological, chemical, and physical properties (Adetunji et al., 2020; Busari et al., 2015; Dabney et al., 2001; Lal & Kimble, 1997; Pierce, 1998; Reicosky & Forcella 1998). Additionally, cover crops and conservation tillage have been shown to increase water storage capacity, which can reduce the need for irrigation (Ali et al., 2017; Arriaga & Balkcom, 2005; Frye & Blevins, 1989).

Water availability is one of the factors that limit peanut production, causing irrigation to be one of the critical factors in production. Irrigation management, such as irrigation scheduling, provides crops with right quantity water when necessary. Irrigation scheduling improves irrigation efficiency, reducing the applications of water. Increased irrigation efficiency not only helps reduce water-use, but also decreases non-point source pollution and has been shown to increase yields in certain crops (Chauhan et al., 2013; El Afandi et al., 2010; Saccon, 2018; Wanjura et al., 2002). While irrigation management implementation costs can be high, research has shown that reduced costs can compensate for large implementation costs (Spencer et al., 2019).

While research on BMPs has shown that input costs can be effectively reduced, producers are hesitant to adopt due to uncertainty of the impact on yields and farm profitability. This research aims to determine the impact of conservation technologies on peanut production in Georgia by quantifying the economic impact of implementing bundles of BMP. BMP bundles were evaluated at three levels: minimal, typical, and intensive adoption of conservation technologies. Management System 1 represents the intensive adoption of conservation technologies and is the most sustainable of the systems. Management System 2 represents practices that are typical of peanut producers in the region. Management System 3 is the minimal adoption of conservation technologies and is the least sustainable of the systems. We also seek to identify the risk efficient management system for peanut producers.

4.3 Data and Methods

4.3.1 Management Practices and Soil and Water Assessment Tool

Peanut management practices were evaluated at three scenario levels: intensive, minimal, and typical implementation of conservation technologies. These management practices were developed based on interviews with extension agents and producers and include current land-use practices in the region. Management System 1 (MS 1) is the most sustainable of the systems. Producer's in MS 1 implement the most conservation practices of the three systems, such as strip tillage, soil moisture sensors, and cover crops. Management System 2 (MS 2) represents practices that are typical of producers in the area. They implement some conventional practices along with conservation practices, such as more efficient irrigation management and less fertilizer application than in Management System 3. Producers in Management System 3 (MS 3) are hesitant to change management practices, which is why they implement the most conventional practices, such as conventional tillage, minimum irrigation management, and no cover crops. MS 3 is the least sustainable of the management systems and likely to result in the most nitrogen leaching. Table 2 outlines the exact characteristics of the three peanut management systems.

Table 6. Best Management Practice Bundles for Peanut Production

	Management System 1	**Management System 2**	**Management System 3**
Tillage	Strip Tillage	Conventional Tillage	Conventional Tillage
Vine Residue	Leave on Field	Leave on Field	Leave on Field
Irrigation Equipment	Soil Moisture Sensors (SMS)	None	None
Irrigation Management	Monitor SMS	UGA Checkbook	Minimum 1 ac-in per week
Irrigation Efficiency	85% efficient	80% efficient	70% efficient
Fertilizer Equipment	Custom spread Lime and Gypsum	Custom Spread Lime and Gypsum	Custom Spread Lime and Gypsum
Soil Fertility Management	Soil + Tissue Test	None	None
Fertilizer	½ ton lime, ½ ton Gypsum	½ ton Lime, ½ ton Gypsum	½ ton Lime, ½ ton Gypsum, 2 ton Chicken Litter, prior to plant
Cover Crops	Rye, no bailing	None	None

The Soil and Water Assessment Tool (SWAT) is a watershed scale model that uses soil, land-use, and management characteristics to forecast the impact on yield, water, and chemical usage (Neitsch et al., 2009). SWAT is a physically based model, which can quantify the impact of alternative characteristics, such as land management actions, climate, and other input data on output variables. SWAT is often used to evaluate the impact of land-use alternatives on water quality and quantity, erosion control, and other environmental conditions. The SWAT modeling process consists of model setup, calibration, and confirmation, then output data for yield, water, and nutrient totals. The characteristics of each management system were input into the SWAT model and yield, irrigation, and nitrate loss were generated for each system in this study.

4.3.2 Enterprise Budgeting and Economic Simulation

To capture the different costs of each management system we created enterprise budgets at each scenario level: intensive, typical, and minimal implementation of BMPs. The enterprise budgets were created based on the University of Georgia’s 2021 Irrigated Peanut Budget (Smith, 2021) and updated based on interviews with extension agents and producers in the region. These updates include farm-scale production costs for current land use practices and conservation technologies. The enterprise budgets included the 2021 Center Pivot, 160 Acres, Electric Irrigation Budget (Bhattarai et al., 2021) to incorporate the irrigation management costs and the variable irrigation costs associated with each management system. We then calculated net returns from the enterprise budgets using the following formula:

$$\begin{gathered} Net\ Returns_i = Yield_{it} \times Price_t - Irrigation\ Variable\ Costs_{it} - \\ Fertilizer\ Variable\ Costs_{it} - Other\ Fixed\ Costs_{it} - Other\ Variable\ Costs_{it} \end{gathered} \tag{12}$$

where *i* is used to denote each management system (MS 1, MS 2, MS 3) and *t* is the year from 1990 to 2016. The impact of production practices and weather conditions were captured by simulating 500 draws of net returns for each management system using Latin Hypercube sampling. For each draw of net returns peanut price, peanut yield, and the amount of in-season irrigation were empirically defined using a univariate simulation. This function assigns probabilities and distribution of the simulated data based on the observed data (Richardson et al., 2008). A multivariate distribution between price and yield would simulate the impact of peanut producers implementing BMP bundles on a larger scale. A univariate empirical distribution of price and yield allowed us to simulate the impact of BMP bundles at the farm-scale.

Historic annual peanut price was collected from the United States Department of Agriculture National Agricultural Statistics Service (USDA/NASS). Peanut Enterprise budgets were created based on 2021 UGA Extension Budgets, therefore peanut price was converted to 2021 values uses Personal Consumption Expenditures (PCE) using the following formula (U.S. Bureau of Economic Analysis, 1959):

$$Real\ Price_t = \frac{PCE_{2021}}{PCE_t} \times nominal\ price_t \tag{13}$$

The Monte Carlo Method and Latin Hypercube method of sampling were both used to simulate yield totals. These simulations were validated using the compare two series function in Simulation and Econometrics to Analyze Risk (SIMETAR) (Richardson et al., 2008). This function tests means using the Student’s T-test and variance using the F-Test. While both methods failed to reject the null hypothesis of equal means and variance, the critical values and p-values that resulted from Latin Hypercube Sampling were more favorable. The results of the tests are outlined in Table 6. Thus, the Latin Hypercube method was used for all simulations, including peanut yield, peanut price, and in-season irrigation amounts.

Table 7. Hypothesis Test Results for Latin Hypercube and Monte Carlo Simulation Method for Peanut

	Test Value	Critical Value	P-Value	Test Result
Latin Hypercube Simulation Method				
2 Sample T-Test	-0.14	2.37	0.891	Fail to Reject H0 that Means are Equal
F Test	1.33	1.52	0.128	Fail to Reject the H0 that the Variances are Equal
Monte Carlo Simulation Method				
2 Sample T-Test	-0.36	2.37	0.719	Fail to Reject H0 that Means are Equal
F Test	1.33	1.52	0.085	Fail to Reject the H0 that the Variances are Equal

4.3.3 Stochastic Efficiency with Respect to a Function

Stochastic efficiency with respect to a function (SERF) was used to determine the risk-efficient management system for producers. SERF uses certainty equivalents (CEs) to order a set of risky choices. A CE is the sum of money that would cause a decision-maker to be indifferent between the guaranteed sum and the risky outcome, it takes the functional form:

$$CE\ (w, r) = U^{-1}(w, r) \tag{14}$$

Where U is the specified utility function, w is wealth, and r is the risk aversion coefficient. Anderson and Dillon (1992) classified the measure of risk aversion proportional to wealth as the relative risk aversion coefficient (RRAC) that ranges from 0 (risk neutral) to 4 (extremely risk averse). The RRAC can be transformed into an absolute risk aversion coefficient (ARAC)by dividing by net returns. Average net returns across management systems for peanut production were $1,731.47 per hectare, therefore the ARAC ranged from 0 to 0.0023. We specified a negative exponential utility function, assuming that as wealth increases the producer will not take on more risk. The functional form of the negative exponential utility function is:

$$U(w) = -exp(-r_a w) \tag{15}$$

The risk premium (RP) represents the loss or gain for a producer to switch from their current management system *j* to an alternative management system *i* would be calculated as follows:

$$RP_{i,j} = CE_i - CE_j \tag{16}$$

If the resulting RP is positive, the dollar value indicates the gains to a producer if they were to switch practices to the alternative management system. If the RP is negative, the value indicates the losses to a producer if they were to change management practices to the alternative management system.

4.4 Results

4.4.1. Impact of Conservation Technologies

The SWAT simulated yield, irrigation, and nitrate leaching data for each management system are summarized in Table 7.

Yield

Table 7 shows that conservation technologies negatively impacted total peanut yield reducing average yields by 232.6 kilograms per hectare from MS 2. The highest average yields were under MS 3 at 5,888.60 kilograms per hectare, followed by MS 2 with 5,792.58 kilograms per hectare. The smallest average yields were 5,559.98 kilograms per hectare under MS 1. The yield totals also showed that conservation technologies negatively impacted yield stability, with MS 1 having the highest standard deviation of the management systems.

Irrigation

MS 1 irrigation amounts were 178 mm to 256 mm less than MS 2 and MS 3 on average, showing that soil moisture sensors were successful at reducing irrigation totals. The UGA checkbook method used by producers in MS 2 averaged higher irrigation totals than MS 1, but was less than MS 3 at an average of 132.14 mm per year. MS 3 totals were highest of each of the management systems, averaging 204.30 mm per year. These values show that irrigation management was successful at reducing overall irrigation amounts in peanut production. MS 1 decreased the average amount of in-season irrigation by 71% and 81% from MS 2 and MS 3, respectively.

Nitrate Leaching

As expected, MS 1 led to the least amount of nitrate leaching of all three management systems, with some years resulting in 0 kilograms per hectare per year of leaching. Minimum nitrate leaching in MS 1 was due to the intensive adoption of conservation technologies, such as conservation tillage, fertilizer timing, irrigation management and cover crops. Average nitrate leaching in MS 2 was 8.93 kilograms per hectare per year. While fertilizer amounts in MS 2 were the same as MS 1, leaching amounts in MS 2 were the second highest of the management systems, likely due to higher irrigation amounts. Producers implementing MS 3 applied the largest fertilizer and irrigation amounts of the systems, which is why it resulted in the highest nitrate leaching of 27.02 kilograms per hectare per year.

Table 8. Summary of Statistics for SWAT Generated Peanut Data

	Average	Minimum	Maximum	Standard Deviation
Yield (kg/ha)				
Management System 1	5559.98	3918.75	6625.55	678.11
Management System 2	5792.58	4331.51	6627.50	579.33
Management System 3	5888.60	4394.68	6634.72	520.87
Irrigation (mm)				
Management System 1	73.38	38.1	114.3	22.35
Management System 2	250.98	132.14	365.09	55.30
Management System 3	329.49	204.30	438.13	67.91
Nitrate Leached (kg/ha/yr)				
Management System 1	0.69	0	5.01	1.07
Management System 2	8.93	0.25	20.63	5.30
Management System 3	27.02	7.90	52.45	13.75

Cost per Hectare

We evaluated the cost per hectare for each management system using static values for yield, irrigation, and price per pound. Conservation technologies were shown to reduce the cost per hectare for management systems, with MS 1 costing between $6.61 and $172.70 less per hectare than the other management systems. Categorized costs per hectare can be seen in Figure 4. While the implementation of conservation technologies in MS 1 increased some production costs, they successfully reduced irrigation and fertilizer variable costs and general fixed and variable costs. Strip tillage implemented in MS 1 had a net negative effect on best management practice fixed costs, lower costs coming from reductions in machinery and fuels. This indicates that the fixed costs of implementing BMPs were outweighed by savings.

High general fixed and general variable, irrigation variable, and fertilizer variable costs led MS 3 to be the most expensive management system for producers to implement. Preharvest and harvest machinery were the same for MS 3 and MS 2, however MS 3 resulted in higher management and overhead costs. Fertilizer variable costs for MS 3 were $185.20 more than MS 1 and MS 2 per hectare, which is likely caused by the application of chicken litter in MS 3.

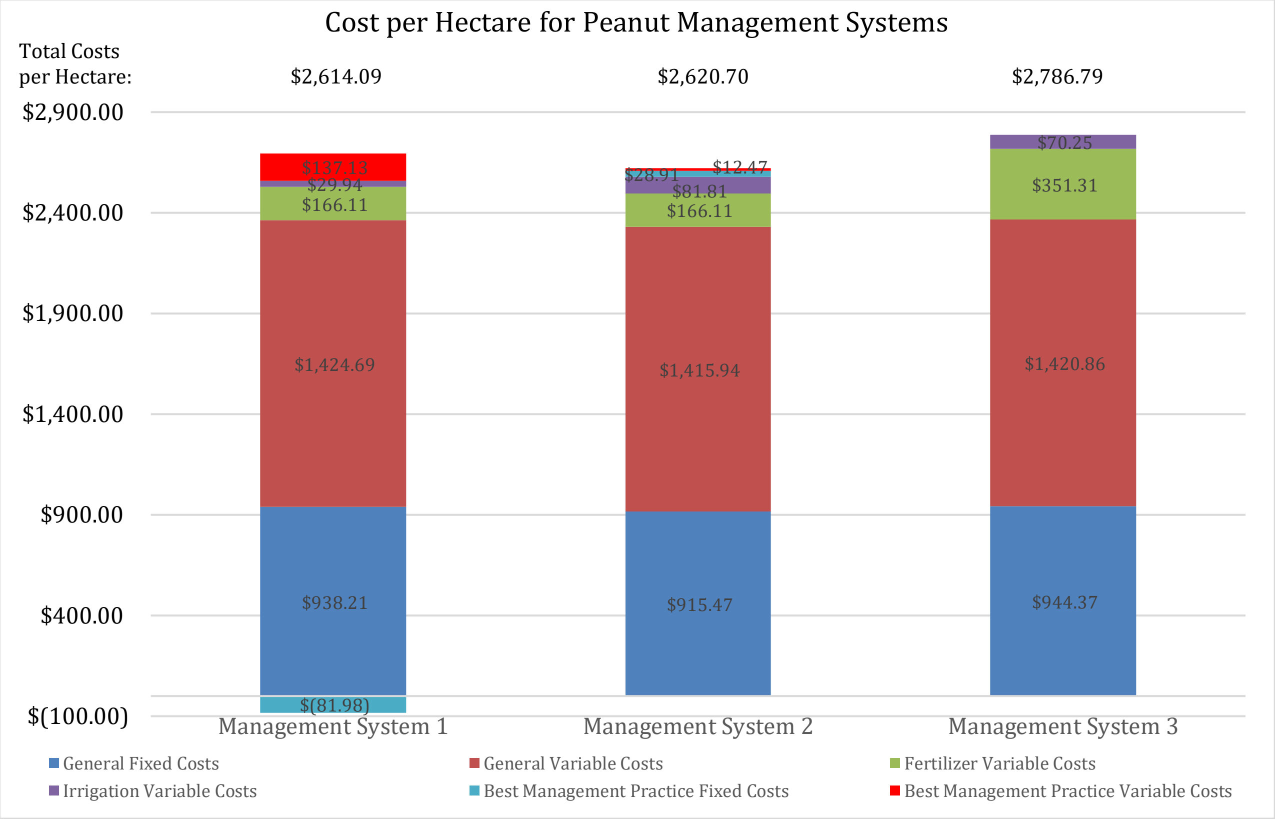

Figure 5. Cost per Hectare for Peanut BMP Bundles

4.4.2. Net Returns

Table 9. Summary of Simulated Peanut Net Returns per Hectare

	Average	Minimum	Maximum	Standard Deviation
Net Returns ($/ha)				
Management System 1	$1,712.45	($284.59))	$6,094.45	$1,357.22
Management System 2	$1,793.23	($399.26)	$6,359.17	$1,371.49
Management System 3	$1,688.72	($671.96)	$5,927.11	$1,387.69

The simulation of net returns is summarized in Table 9. MS 3 offered the least desirable net returns, having the possibility of the largest losses and the smallest gains per hectare. MS 3 also offered the smallest average net returns across management systems at $1,688.72 per hectare. MS 1 has the second highest possible net returns of all three systems at an average of

$1,712.45 per hectare, smaller returns on average than MS 2 but larger than MS 3. The average returns per hectare for MS 2 were higher than the other systems by $80.78 for MS 1 and $104.50 for MS 3.

A Stoplight Chart was used to determine the probability of different amounts of net returns occurring. The Stoplight Chart in Figure 6 depicts the probability of net returns falling below the bottom 25% of simulated values ($554.55) and exceeding the top 25% of simulated values ($2,866.93), and the probability of values falling in between this range. The Stoplight results depict net return probabilities of MS 1 and MS 2 being very similar. MS 2 has a 27% chance of exceeding $2,866.93 per hectare, while MS 1 and MS 3 both have only a 24% chance. The Stoplight chart also shows that MS 3 has a 29% chance of generating net returns below $554.55, which is the largest probability of the management systems. While the Stoplight results are helpful in evaluating risky choices, they do not include the magnitude of returns in each category or the risk attitudes of the decision makers.

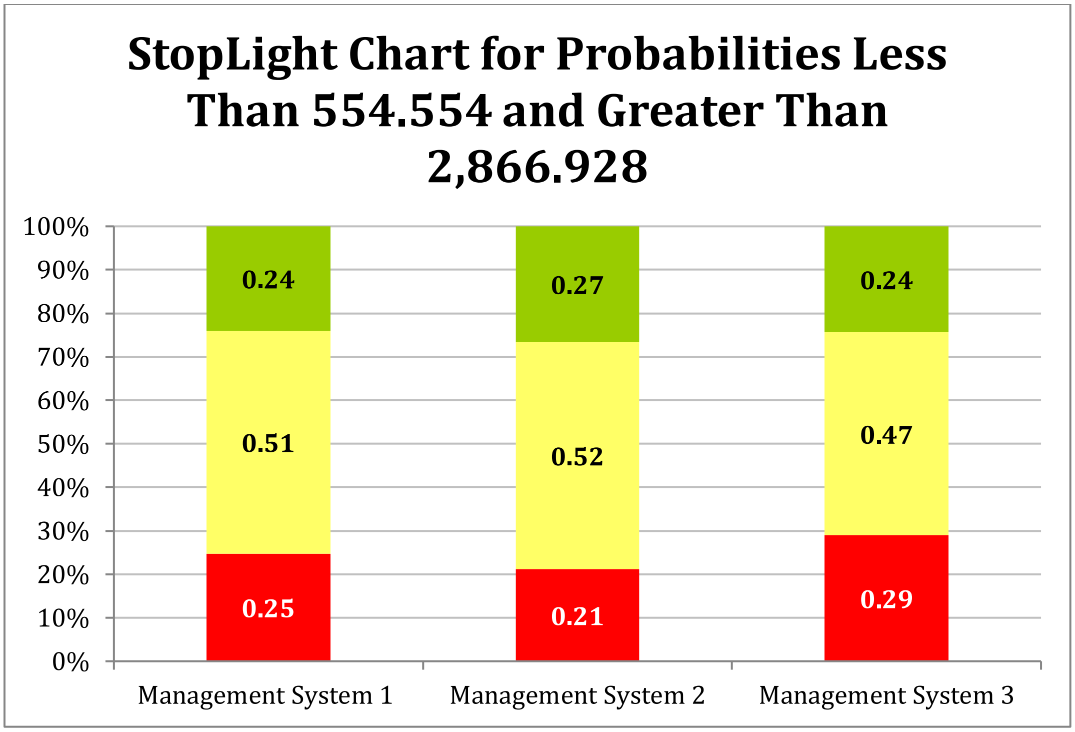

Figure 6. Stoplight Chart for Simulated Peanut Net Returns per Hectare

4.4.3. Stochastic Efficiency with Respect to a Function

Certainty Equivalents

CEs were calculated using a negative exponential utility function. Results of CEs across ARACs are depicted in Figure 7. While the chart indicates that certainty equivalents for all three management systems are similar, the results indicate that MS 2 is the most preferred system for producers across all ARACs. CEs for MS 2 range from $304 to $726 per hectare, the highest of all the systems. MS 1 is closely preferred behind MS 2 with CEs ranging from $275 to $693 per hectare. Across ARACs MS 3 remains the least preferred by producers with the smallest CEs at $256 to $683 per hectare.

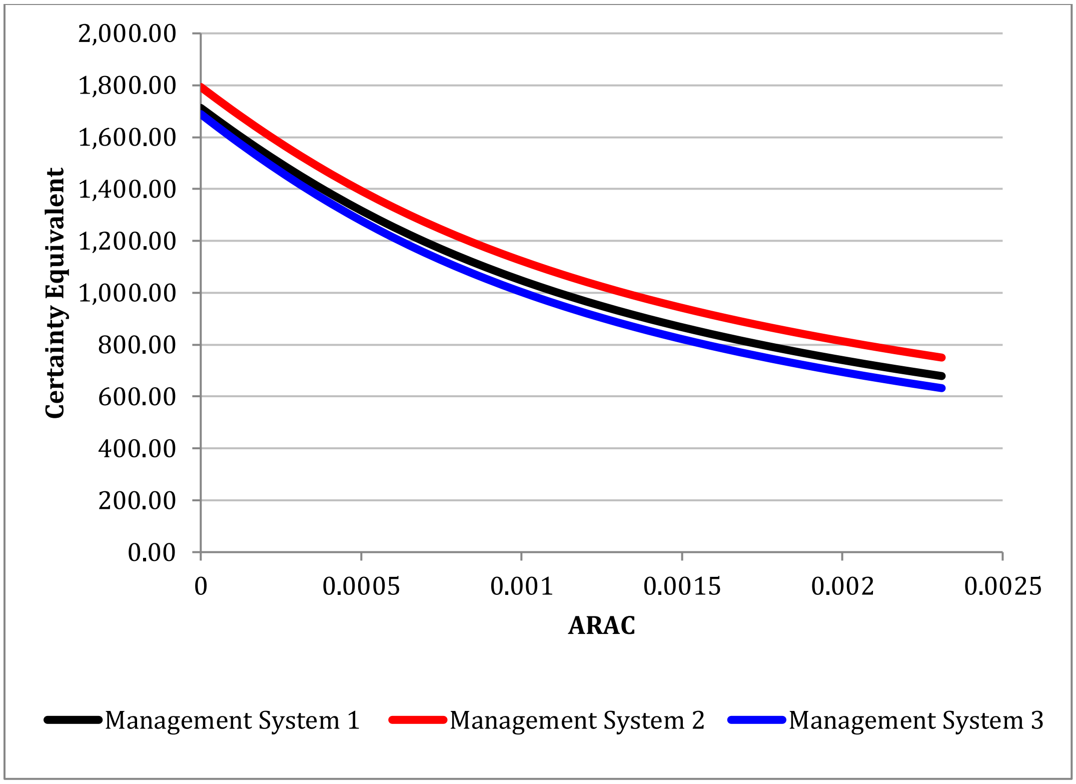

Figure 7. SERF under a Negative Exponential Utility Function for Peanut Production

Risk Premiums

Risk premiums for the management systems can be seen in Figure 8. MS 1 was set as the base system, because producer adoption of the conservation technologies is encouraged. Risk premiums for MS 2 are negative, indicating producers would realize losses switching from MS 2 to MS 1. Producers currently implementing MS 3 would realize gains if they were to switch to MS 1, ranging from $23.72 to $46.66 per hectare. To encourage adoption of MS 1, producers currently implementing MS 2 would need a payment ranging from $71.29 to $80.78 per hectare.

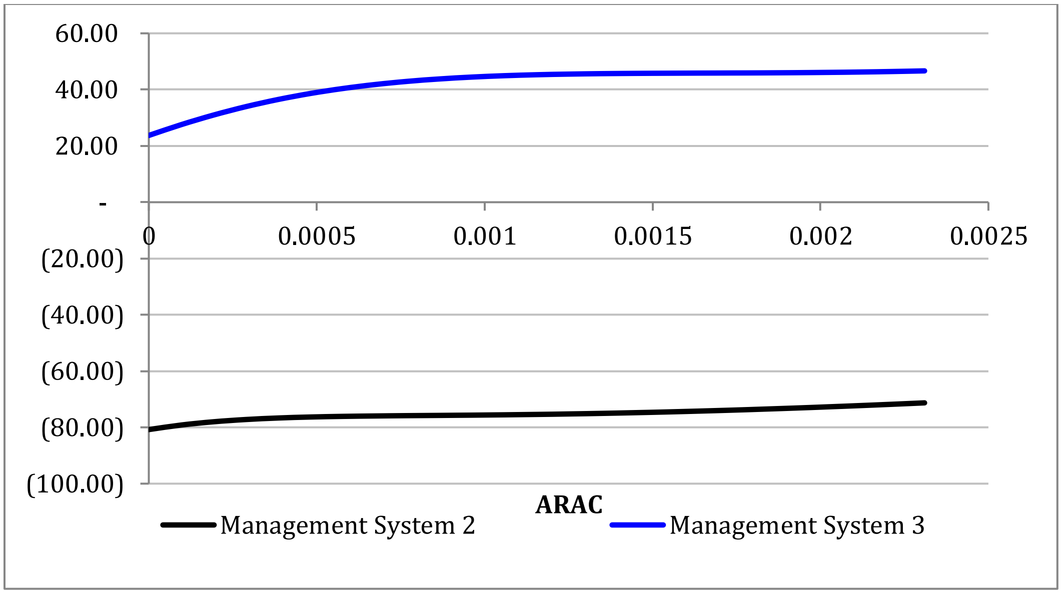

Figure 8. Risk Premiums Relative to Net Returns per Hectare for Peanut Management System 1

Table 10. Risk Premiums for Peanut Management Systems at ARACs Relative to MS 1

	Risk Neutral	Somewhat Risk Averse	Rather Risk Averse	Very Risk Averse	Extremely Risk Averse
	0.00	0.0058	0.0012	0.0017	0.0023
Management System 2	($80.78)	($376.09)	($75.40)	($73.89)	($71.29)
Management System 3	$23.72	$40.39	$45.28	$45.91	$46.66

4.5 Conclusion

This project evaluated the economic impact of bundles of conservation technologies on farm-scale production cost of peanuts and sought to determine the risk efficient management system using SERF. Implementation of conservation technologies in peanut production, such as strip tillage, soil moisture sensors, and cover crops, showed to have a negative impact on total yields. Increased fertilizer applications showed to increase total yield amounts. Conservation technologies did, however, effectively reduce production costs. The decreased production costs associated with MS 1 were not large enough to compensate for the reduced yields. However, the yield totals and production costs for the typical adoption of conservation technologies (MS 2) balanced the trade-off best.

When accounting for producer's risk attitudes, we found that the least preferred management system was the minimal adoption of conservation technologies, MS 3. This is likely due to the large fertilizer and machinery costs associated with this system, which creates a heavy reliance on current input prices, such as fuel and fertilizers. Overall, MS 2 was the most preferred system by producers who were risk neutral to extremely risk averse (across all ARACs). Risk premiums can provide important policy implications. If the goal is to encourage more sustainable production practices, such as those in MS 1, we found producers currently implementing MS 2 will require a payment from $71 to $81 per hectare. However, if producers were implementing MS 3 were to switch to MS 1, they would realize gains from $24 to $47 per hectare.

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Chapter 5

Conclusion

Farm-Scale Impacts

Conservation technologies implemented in Management System 1 were shown to reduce yields in both peanut and cotton production in the study region. Yield reductions for both crops under the intensive conservation management system can be attributed to larger fertilizer applications in the typical and minimal adoption of conservation technologies. However, the best management practice (BMP) bundles implemented in were effective at reducing irrigation, fertilizer, and general fixed and variable costs. This led to costs per hectare in Management System 1, the intensive adoption of conservation technologies, to be smallest in peanut production. While BMP bundles reduced irrigation and fertilizer costs in cotton production, implementation of the conservation technologies in Management System 1 increased costs per hectare from the typical adoption of BMPs in Management System 2.

Policy Implications

Peanut and cotton producers across all levels of risk aversion were shown to prefer the typical adoption of conservation technologies, Management System 2. Subsidization of conservation technologies is one of the main policy instruments to change producer's production practices.

Management System 3, the minimal adoption of conservation technologies, was ranked as second most preferred for cotton producers. The subsidy amount to encourage cotton producers to implement the conservation technologies in Management System 1 is determined based on the practice they are currently implementing. Producers implementing Management System 2 would require a subsidy ranging from $313 to $406 per hectare, depending on their level of risk aversion. Producers implementing Management System 3 would need a subsidy from $222 to $375 per hectare to implement Management System 1.

Management System 2 was identified as the risk-efficient bundle for peanut production. Producers currently implementing Management System 2 could be encouraged to adopt Management System 1 through a subsidy of $71 to $80. Management System 3 was least preferred by peanut producers. Producers currently implementing Management System 3 would realize gains if they were to implement conservation practices in Management System 1 ranging from $24 to $47 per hectare.

Agriculture is a critical industry in Georgia and sustainable production practices are becoming increasingly important. Best management practices (BMPs) can improve resource efficiency and production conditions, while decreasing input costs. Policies encouraging sustainable production practices will be essential for the future. Our research evaluated the farm-scale impact of bundles of BMPs and identified the risk efficient bundle for cotton and peanut production, however producers have a degree of flexibility between the practices in each system.

Appendix

Table 11. Cotton Enterprise Budget for Management System 1

Strip-Tillage, Irrigated Cotton - Level 1
Tifton, Georgia
Estimated Costs and Returns

Expected Yield:**1390.6** Lb
Expected Price:**$0.87**/Lb
Expected Income: $1,209.80

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**Cents/Lb**
XtendFlex Seed	thousand	39.93	$2.70	$107.81	7.75
Lime	ton	0.33	$48.00	$15.84	1.14
Fertilizer					
Nitrogen	pounds	110	$ 0.45	$49.50	3.56
Phosphate	pounds	70	$ 0.38	$26.60	1.91
Potash	pounds	70	$ 0.30	$21.00	1.51
Boron	acre	1	$6.00	$6.00	0.43
Weed Control	acre	1	$72.26	$72.26	5.20
Hand Weeding	acre	1	$10.00	$10.00	0.72
Insect Control	acre	1	$20.75	$20.75	1.49
PGR	ounces	36	$0.05	$1.84	0.13
Defoliant and Boll Opener	ounces	1	$14.26	$14.26	1.03
Preharvest Machinery					
Fuel and Lube	gallon	7.5	$2.00	$15.05	1.08
Repairs and Maintenance	acre	1.0	$13.70	$13.70	0.99
Harvest Machinery					
Round Module Picker					
Fuel and Lube	gallon	6.4	$2.00	$12.74	0.92
Repairs and Maintenance	acre	1	$ 27.45	$27.45	1.97
Labor	hours	1.5	$13.50	$20.25	1.46
Irrigation*	applications	4.67	$5.29	$24.71	1.78
Crop Insurance	acre	1	$10.00	$10.00	0.72
Interest on Operating Capital	precent	$234.87	5.5%	$12.92	0.93
Ginning and Warehousing	acre	1.0	$39.87	$39.87	2.87
Nutrient Monitoring/Mgt	Acre	1.0	$ 3.00	$3.00	0.22
Grid Sampling & Custom Spread	Acre	1.0	$ 23.00	$23.00	1.65
Tissue Sampling	Acre	0.1	$25.00	$2.50	0.18
Cover Crop Seed	Lbs	51.0	$ 0.25	$15.93	1.15
Cover Crop Burndown	Acre	1.0	$12.90	$12.90	
Total Variable Costs:				**$ 579.86**	**40.77**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1	$ 84.40	$ 84.40	6.07
Harvest Machinery	acre	1	$130.14	$130.14	9.36
Irrigation	acre	1	$141.26	$141.26	10.16
Soil Moisture System	acre	1	$ 2.19	$ 2.19	
General Overhead	% of VC	$ 579.86	5%	$28.99	2.08
Management	% of VC	$ 579.86	5%	$ 28.99	2.08
Total Fixed Costs				**$415.98**	**29.76**
Total Costs				**$995.85**	**70.53**
Net Income per Acre				**$213.95**	

Table 12. Cotton Enterprise Budget for Management System 2

Conventional Tillage, Irrigated Cotton – Level 2
South Georgia, 2021
Estimated Costs and Returns

Expected Yield:**1390.6** Lb
Expected Price:**$0.87**/Lb
Expected Income per Acre: $1,209.80

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**Cents/Lb**
XtendFlex Seed	thousand	39.93	$2.70	$107.81	7.75
Lime	ton	0.33	$48.00	$15.84	1.14
Fertilizer					
Nitrogen	pounds	70	$0.30	$21.00	1.51
Phosphate	pounds	70	$0.38	$26.60	1.91
Potash	pounds	70	$0.30	$21.00	1.51
Boron	acre	1	$6.00	$6.00	0.43
Poultry Litter	Ton	2	$37.49	$74.98	5.39
Weed Control	acre	1	$53.68	$53.68	3.86
Hand Weeding	acre	1	$10.00	$10.00	0.72
Insect Control	acre	1	$20.75	$20.75	1.49
PGR	ounces	36	$0.05	$1.84	0.13
Defoliant and Boll Opener	ounces	1	$14.26	$14.26	1.03
Preharvest Machinery					
Fuel and Lube	gallon	5.4	$2.00	$10.86	0.78
Repairs and Maintenance	acre	1.0	$13.70	$13.70	0.99
Harvest Machinery					
Round Module Picker					
Fuel and Lube	gallon	6.4	$2.00	$12.74	0.92
Repairs and Maintenance	acre	1	$27.45	$27.45	1.97
Labor	hours	1.2	$13.50	$15.82	1.14
Irrigation*	applications	6.75	$4.31	$29.06	2.09
Crop Insurance	acre	1	$10.00	$10.00	0.72
Interest on Operating Capital	precent	$ 246.69	5.5%	$13.57	0.98
Ginning and Warehousing	acre	1.0	$39.87	$39.87	2.87
Nutrient Monitoring/Mgt	Acre	1.0	$1.00	$1.00	0.07
Tissue Sampling	Acre	0.1	$25.00	$2.50	0.18
Soil Sampling	Acre	0.1	$7.00	$0.70	0.05
Total Variable Costs:				**$551.01**	**39.62**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1	$50.16	$50.16	3.61
Harvest Machinery	acre	1	$130.14	$130.14	9.36
Irrigation	acre	1	$141.26	$141.26	10.16
General Overhead	% of VC	$ 579.86	5%	$28.99	2.08
Management	% of VC	$ 579.86	5%	$28.99	2.08
Total Fixed Costs				**$379.55**	**27.29**
Total Costs				**$930.56**	**66.92**
Net Returns Per Acre				**$279.24**	

Table 13. Cotton Enterprise Budget for Management System 3

Conventional Tillage, Irrigated Cotton - Level 3
South Georgia, 2021
Estimated Costs and Returns

Expected Yield: **1390.6** Lb
Expected Price: **$0.87**/Lb
Expected Income per Acre: $1,209.80

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**Cents/Lb**
XtendFlex Seed	thousand	39.93	$2.70	$107.81	7.75
Lime	ton	0.33	$48.00	$15.84	1.14
Fertilizer					
Nitrogen	pounds	120	$0.45	$54.00	3.88
Phosphate	pounds	70	$0.38	$26.60	1.91
Potash	pounds	70	$0.30	$21.00	1.51
Boron	acre	1	$6.00	$6.00	0.43
Poultry Litter	ton	2	$37.49	$74.98	5.39
Weed Control	acre	1	$53.68	$53.68	3.86
Hand Weeding	acre	1	$10.00	$10.00	0.72
Insect Control	acre	1	$20.75	$20.75	1.49
PGR	ounces	36	$0.05	$1.84	0.13
Defoliant and Boll Opener	ounces	1	$14.26	$14.26	1.03
Preharvest Machinery					
Fuel and Lube	gallon	6.9	$2.00	$13.88	1.00
Repairs and Maintenance	acre	1.0	$13.70	$13.70	0.99
Harvest Machinery					
Round Module Picker					
Fuel and Lube	gallon	6.4	$2.00	$12.74	0.92
Repairs and Maintenance	acre	1	$27.45	$27.45	1.97
Labor	hours	1.4	$13.50	$18.23	1.31
Irrigation*	applications	9.85	$3.54	$34.87	2.51
Crop Insurance	acre	1	$10.00	$10.00	0.72
Land Rent	acre	1	$0.00	$0.00	0.00
Interest on Operating Capital	precent	$ 268.81	$0.06	$14.78	1.06
Ginning and Warehousing	acre	1.0	$39.87	$39.87	2.87
Total Variable Costs:				**$592.27**	**42.59**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1	$61.23	$61.23	4.40
Harvest Machinery	acre	1	$130.14	$130.14	9.36
Irrigation	acre	1	$141.26	$141.26	10.16
General Overhead	% of VC	$ 579.86	$0.05	$28.99	2.08
Management	% of VC	$ 579.86	$0.05	$28.99	2.08
Total Fixed Costs				**$390.62**	**28.09**
Total Costs				**$982.89**	**70.68**
Net Returns per Acre				**$226.91**	

Table 14. Peanut Enterprise Budget for Management System 1

Irrigated Peanut, Strip Tillage - Level 1
6-Row Equipment
South Georgia, 2020
Estimated Costs and Returns

Expected Price: **0.25 $/lb**
Expected Yield: **4960.50 lb/ac**
Expected Income: **1230.02**

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**$/lb/ac**
Cover Crop Seed	bushel	1.5	$17.00	$25.50	$0.01
Seed *	pounds	140	$0.90	$126.00	$0.03
Inoculant	pounds	5	$1.85	$9.25	$0.00
Lime/Gypsum **	ton	0.5	$110.00	$55.00	$0.01
Fertilizer					
Boron	pounds	0.5	$6.00	$3.00	$0.00
Phosphate	pounds	0	$0.38	$0.00	$0.00
Potash	pounds	0	$0.30	$0.00	$0.00
Weed Control	acre	1	$52.16	$52.16	$0.01
Handweeding	acre	1	$15.00	$15.00	$0.00
Insect Control	acre	1	$54.20	$54.20	$0.01
Scouting	acre	1	$10.00	$10.00	$0.00
Disease Control ***	acre	1	$92.22	$92.22	$0.02
Preharvest Machinery					
Fuel	gallon	5.2	$2.00	$10.42	$0.00
Repairs and Maintenance	acre	1	$22.27	$22.27	$0.00
Harvest Machinery					
Fuel	gallon	7.9	$2.00	$15.77	$0.00
Repairs and Maintenance	acre	1	$32.04	$32.04	$0.01
Labor	hours	2.0	$13.50	$27.51	$0.01
Irrigation****	applications	3.00	$4.04	$12.12	$0.00
Crop Insurance	acre	1	$18.00	$18.00	$0.00
Interest on Operating Capital	percent	$277.48	5.5%	$15.26	$0.00
Cleaning	lb/ac	0.8	$20.00	$16.37	$0.00
Drying	lb/ac	1.7	$30.00	$49.85	$0.01
Marketing	lb/ac	2.5	$3.00	$7.44	$0.00
NPB Checkoff	dollars	0.0	$880.49	$8.80	$0.00
Nutrient Monitoring/Mgt	Acre	1.0	$3.00	$3.00	$0.00
Irrigation Monitoring/Mgt	Acre	1.0	$7.50	$7.50	$0.00
Grid Sampling & Custon Spreading	Acre	$1.00	23	$23.00	$0.00
Total Variable Costs:				**$711.68**	**$0.14**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1	$34.24	$34.24	$0.01
Harvest Machinery	acre	1	$97.79	$97.79	$0.02
Irrigation	acre	1	$141.26	$141.26	$0.03
Soil Moisture System	acre	1	$2.19	$2.19	$0.00
General Overhead	% of VC	$ 711.68	5%	$35.58	$0.01
Management	% of VC	$ 711.68	5%	$35.58	$0.01
Total Fixed Costs				**$346.65**	**$0.07**
Total Costs				**$1,058.34**	**$0.21**
Net Returns Per Acre				**$171.68**	

Table 15. Peanut Enterprise Budget for Management System 2

Conventional Tillage, Irrigated Peanut - Level 2
South Georgia, 2022
Estimated Costs and Returns

Expected Price: **0.25 $/lb**
Expected Yield: **4960.50** lb/ac
Expected Income: **1230.02**

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**$/lb/ac**
Seed *	pounds	140	$0.90	$126.00	$ 0.03
Inoculant	pounds	5	$1.85	$9.25	$ 0.00
Lime/Gypsum **	ton	0.5	$110.00	$55.00	$ 0.01
Fertilizer					
Boron	pounds	0.5	$6.00	$3.00	$ 0.00
Phosphate	pounds	0	$0.38	$ -	$ -
Potash	pounds	0	$0.30	$ -	$ -
Weed Control	acre	1	$35.55	$35.55	$ 0.01
Handweeding	acre	1	$15.00	$15.00	$ 0.00
Insect Control	acre	1	$54.20	$54.20	$ 0.01
Scouting	acre	1	$10.00	$10.00	$ 0.00
Disease Control ***	acre	1	$92.22	$92.22	$ 0.02
Preharvest Fuel	gallon	10.1	$2.00	$20.20	$ 0.00
Preharvest Repairs & Maintenance	acre	1	$22.27	$22.27	$ 0.00
Harvest Fuel	gallon	8.3	$2.00	$16.60	$ 0.00
Harvest Repairs & Maintenance	acre	1	$32.04	$32.04	$ 0.01
Labor	hours	2.8	$13.50	$37.80	$ 0.01
Irrigation****	applications	16.00	$2.07	$33.12	$ 0.01
Crop Insurance	acre	1	$18.00	$18.00	$ 0.00
Land Rent	acre	1	$ -	$ -	$ -
Interest on Operating Capital	percent	$290.13	5.5%	$15.96	$ 0.00
Cleaning	lb/ac	0.8	$20.00	$16.37	$ 0.00
Drying	lb/ac	1.7	$30.00	$49.85	$ 0.01
Marketing	lb/ac	2.5	$3.00	$7.44	$ 0.00
NPB Checkoff	dollars	0.01	$880.49	$8.80	$ 0.00
Total Variable Costs:				**$678.68**	**$ 0.14**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1	$ 67.87	$67.87	$ 0.01
Harvest Machinery	acre	1	$ 102.04	$102.04	$ 0.02
Irrigation	acre	1	$ 141.26	$141.26	$ 0.03
General Overhead	% of VC	$ 711.68	5%	$35.58	$ 0.01
Management	% of VC	$ 711.68	5%	$35.58	$ 0.01
Total Fixed Costs				**$382.34**	**$ 0.08**
Total Costs				**$1,061.01**	**$ 0.21**
Net Returns per Acre				**$169.01**	

Table 16. Peanut Enterprise Budget for Management System 3

6-Row Equipment
South Georgia, 2022
Estimated Costs and Returns

Expected Price: **0.25 $/lb**
Expected Yield: **4960.50 lb/ac**
Expected Income: **1230.02**

Variable Costs	**Unit**	**Amount**	**$/Unit**	**Cost/Acre**	**$/lb/ac**
Seed *	pounds	140	$0.90	$126.00	$0.03
Inoculant	pounds	5	$1.85	$9.25	$0.00
Lime/Gypsum **	ton	0.5	$110.00	$55.00	$0.01
Fertilizer					
Boron	pounds	0.5	$6.00	$3.00	$0.00
Phosphate	pounds	0	$0.67	$0.00	$0.00
Potash	pounds	0	$0.68	$0.00	$0.00
Chicken Litter	ton	2	$37.49	$74.98	$0.02
Weed Control	acre	1	$35.55	$35.55	$0.01
Handweeding	acre	1	$15.00	$15.00	$0.00
Insect Control	acre	1	$54.20	$54.20	$0.01
Scouting	acre	1	$10.00	$10.00	$0.00
Disease Control ***	acre	1	$92.22	$92.22	$0.02
Preharvest Fuel	gallon	9.7	$2.00	$19.31	$0.00
Preharvest Repairs & Maintenance	acre	1	$22.27	$22.27	$0.00
Harvest Fuel	gallon	7.9	$2.00	$15.77	$0.00
Harvest Repairs & Maintenance	acre	1	$32.04	$32.04	$0.01
Labor	hours	2.6	$13.50	$34.66	$0.01
Irrigation****	applications	18.00	$1.58	$28.44	$0.01
Crop Insurance	acre	1	$18.00	$18.00	$0.00
Land Rent	acre	1	$0.00	$0.00	$0.00
Interest on Operating Capital	percent	$ 322.85	$0.06	$17.76	$0.00
Cleaning	lb/ac	0.8	$20.00	$16.37	$0.00
Drying	lb/ac	1.7	$30.00	$49.85	$0.01
Marketing	lb/ac	2.5	$3.00	$7.44	$0.00
NPB Checkoff	dollars	$ 0.01	$880.49	$8.80	$0.00
Total Variable Costs:				**$ 745.92**	**$ 0.15**
Fixed Costs					
Machinery Depreciation, Taxes, Insurance and Housing					
Preharvest Machinery	acre	1.00	$67.87	$67.87	$0.01
Harvest Machinery	acre	1.00	$102.04	$102.04	$0.02
Irrigation	acre	1.00	$141.26	$141.26	$0.03
General Overhead	% of VC	$711.68	5%	$35.58	$0.01
Management	% of VC	$711.68	5%	$35.58	$0.01
Total Fixed Costs				**$ 382.34**	**$ 0.08**
Total Costs				**$ 1,128.26**	**$ 0.23**
Net Returns per Acre				**$ 101.76**	