Risk Effects on Nitrogen Fertilization and Cost-Share Payments under Alternative Tillage and Cover Crop Systems for Cotton

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Abstract

We determine the effect of downside risk on optimal nitrogen (N) fertilizer rate, tillage, and cover crop decisions, and the influence of risk preferences on incentive payment thresholds required to encourage adoption of cover crops and no-tillage by cotton producers. Data are from a 29-year cotton N rate, tillage, and cover crop experiment in west Tennessee. Tillage and no-tillage cotton using N rates of 0, 30, 60, and 90 lb/acre were planted after hairy vetch, crimson clover, winter wheat, and no winter cover in the experiment. Net returns were calculated using partial budgeting. Antle's flexible moment based model was used to estimate optimal N application, cover crop, and tillage decisions. Certainty equivalents were compared across cover crop and tillage decision to determine incentive payment thresholds that would encourage the adoption of these practices. Certainty equivalents were highest for risk-neutral and moderately risk-averse producers for tillage cotton following no cover. Extremely risk-averse producers preferred no-tillage cotton following no cover. Therefore, we did not find risk benefits from using no-tillage and cover crops in our analysis. The incentive payment thresholds required to encourage the use of cover crops varied with risk preference and were generally lower under no-tillage than under tillage.

Key Words: Cotton, Cover crops, Tillage, Risk

Introduction

The amount of soil surface crop residue that remains in upland cotton fields post-harvest is small relative to other row crops (Nyakatawa, Reddy, and Lemunyon, 2001). Therefore, the soils upon which cotton is produced are subject to higher water-induced soil erosion risk than with other row crops (Nyakatawa, Reddy, and Lemunyon, 2001). Erosion is an especially important issue in the Mid-South United States where soils typically used to grow cotton are sandy or silty, which are naturally prone to soil erosion (Bradley and Tyler, 1996; Boquet et al., 2004), and cotton is an important cash crop, covering an estimated 9.82 million acres planted in 2016 (USDA NASS, 2016). Thus, reducing soil erosion in Mid-South cotton production while maintaining producers' profits is a major challenge for producers in the region.

Winter cover crops and no-tillage are effective practices for reducing soil erosion in cotton production by increasing plant residue on the soil surface in the field (Boquet et al., 2004; Foote at al., 2014; Hanks and Martin, 2007; Kornecki and Price, 2010; Kornecki et al., 2015; Mbuthia et al., 2015; Reiter et al., 2007; Tewolde et al., 2015; Zablotowicz et al., 2011). However, adoption of cover crops and no-tillage remains limited in the Mid-South (Wade, Claassen, and Wallender, 2015). A possible explanation for limited adoption of the aforementioned practices may be the inconsistent profitability and risk management benefits reported for the two practices (Boquet et al., 2004; Dunn et al., 2016; Snapp et al., 2005; Triplett and Dick, 2008).

Cover crops increase production costs through seed, machinery, labor, and other costs incurred to establish and kill the cover crop. Additional revenue through higher cash crop yields are needed to recuperate these costs. In addition, legume covers may reduce nitrogen (N) fertilizer costs for the following cash crop by adding N in the soil. No-tillage can reduce machinery and fuel costs but may increase chemical costs for producers relative to tillage. Changes in expected yields and yield risk determine the profitability of tillage systems since the cost of production for no-till and till are often similar (Triplett and Dick, 2008; Toliver et al., 2012).

Studies of the profitability of cover crops in the Mid-South have reported legume cover crops reducing N fertilizer costs relative to no cover crop or a non-legume cover crop (Hanks and Martin, 2007; Foote et al., 2014; Larson et al., 2001b; Varco, Spurlock, and Sanabria-Garro, 1999). However, net returns from planting cover crops have been reported to be lower (Larson et al., 2001b; Hanks and Martin, 2007), higher (Varco, Spurlock, and Sanabria-Garro, 1999), or equivalent (Foote et al., 2014) to net returns without cover crops. Yield increases and N fertilizer cost savings were not greater than the cost of establishing the cover crop. Similarly, no-till can generate higher net returns than till planting (Hank and Martin, 2007); however, Larson et al. (2001b) found tillage to have higher net returns than no-tillage. Meta-analyses of no-tillage studies conclude that the profitability of no-tillage is unclear (Triplett and Dick, 2008; Toliver yet al., 2012).

Others have found risk management benefits from these practices through reduced yield variability in cotton production (i.e., production risk) (Jaenicke, Frechette, and Larson, 2003; Larson et al., 2001a). Larson et al. (2001a) evaluated the effects of yield variance on optimal N fertilizer rates for cotton production under different cover crop and tillage systems. Optimal N rates for cotton were lower when planting a legume cover crops relative to no cover crop, and optimal N rates for cotton increased after a non-legume cover crop relative to no cover crop.

They reported that optimal N rates for cotton decreased as risk aversion behavior increased with most cover crop systems. The exception was for no-tillage cotton following crimson clover where optimal N fertilizer rates rose with increasing risk aversion. Cover crop under tillage were not preferred by risk-neutral or risk-averse producers; however, legume cover crops under no-tillage would be preferred by highly risk-averse producers. Previous research on the effects of risk on optimal N rates for cotton under various cover crop and tillage practices incorporate yield variance in the economic framework, but do not explicitly consider the effects of downside risk through a lower partial moment measurement (Jaenicke, Frechette, and Larson, 2003; Larson et al., 2001a). Toliver et al. (2012) in a meta-analysis of yields from 442 paired tillage experiments in the United States found mixed risk management benefits of no-tillage cotton using the probability of no-tillage yields below tillage yields as the measure of yield risk. Antle (1987) suggested an empirical model that included variance and skewness into risk analysis. Antle's approach has been used by others (e.g., Boyer et al., 2015; Di Falco and Chavas, 2006) to evaluate crop production practices but has not been applied to evaluating the risk and return tradeoffs of tillage and cover cropping systems.

Soil conservation has been an important goal of US agricultural policy since the1930s as currently exemplified in the Agricultural Act of 2014 (Lubben and Pease, 2014). Supporting that goal is financial assistance to producers for adopting cover crops and no-tillage is available through the Environmental Quality Incentive Program (EQIP) (United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), 2015). This program provides producers with cost-share payments for cover crops (EQIP Practice Code 340) and no-till (EQIP Practice Code 329) that are intended to increase the adoption of these practices relative to no cover crops and conventional tillage (Bergtold et al., 2012; Lichtenberg, 2004). While the number of farms receiving cost-share payments for cover crop and no-tillage practices has increased in recent years (USDA NRCS, 2015), few producers make use of the financial assistance available for implementing these practices (Dunn et al., 2016). Limited participation in EQIP for the aforementioned practices may indicate that the cost-share payments are not compensating for all of the risk and return tradeoffs associated with cover crops and no-tillage.

Therefore, research is needed to measure the long-term profitability and risk management benefits of cover crops and no-tillage relative to no cover crop and conventional tillage production since most of the benefits of these practices such as increase soil organic matter are realized over many years (Boquet et al., 2004; Karlen et al., 2013; Richter et al., 2007). The measurements can provide estimates of sufficient compensation required for cotton producers to adopt cover crops and no-tillage. Furthermore, studies have revealed that risk-averse producers are less likely to adopt a conservation practice due to uncertainty of the impact on yields and profits (Baumgart-Gertz, Prokopy, and Floress, 2012; Arbuckle Jr. and Roesch-McNally, 2015). This means a more risk-averse producer may require a higher cost-share payment to adopt cover crops or no-tillage. Estimating cost-share payments for producers with different risk preferences may provide insight into how production risk impacts the adoption of cover crops and no-tillage.

The objective of this research was to determine the impact of four winter cover crop treatments (no cover crop, hairy vetch, winter wheat, and crimson clover) and two tillage (no-tillage and conventional tillage) systems on optimal N rates and net returns for risk-neutral and risk-averse cotton producers in Tennessee. Estimates for incentive payments needed to encourage the adoption of cover crops and no-tillage were found for risk-neutral and risk-averse producers. Data are from a long-term (29-year) cotton fertilizer, tillage, and cover crop experiment in west Tennessee.

Conceptual Framework

Partial budgeting was used to calculate the expected net returns of different cover crop and tillage systems for upland cotton. Machinery, chemical, and cover crop seed costs vary across these systems along with the optimal N fertilizer rates. Reduction in the cost of N fertilizer resulting from using a cover crop is an important factor in determining the profitability of covers crops. Net returns are defined as

$$(1) \qquad E(\pi_{ij}) = p^c E(y_{ij}) - p^N N_{ij} - c_i - w_j ,$$

where $E(\pi_{ij})$ is the producers expected returns (\$ acre^{-1}) for cotton grown following cover crop i under tillage system j; p^c is the price of cotton lint (\$ lb^{-1}); $E(y_{ij})$ is the expected lint yield (lb acre^{-1}); p^N is the cost of N fertilizer (\$ lb^{-1}); N is the amount of nitrogen fertilizer applied to cotton (lb acre^{-1}); c_i is the cost of establishing the cover crop (\$ acre^{-1}); and w_j is the fixed production cost for each tillage practice (\$ acre^{-1}). A risk-neutral producer would select the tillage system, cover crop species, and N fertilizer rate to maximize expected returns.

However, weather, management practices, diseases, and other unobserved factors introduce variability in expected net returns. To introduce this risk into the producer's decision making framework, assume that preferences for a risk-averse producer are characterized by a utility function $U(\pi_{ij}, r)$, where r is the producer's risk preference level. The utility a producer receives from maximizing profit is converted to monetary terms by inverting the utility function into a certainty equivalent (CE). The CE is the guaranteed return that would make a producer indifferent between the risk-free return and a risky decision. For each cover crop and tillage system, the CE was calculated as the expected net returns (equation 1) less the amount the producer would pay to eliminate risk (i.e., risk premium).

A risk-averse producer applies N fertilizer at a rate that maximizes their CE:

$$\max_{N_{ij}} \mathrm{CE}_{ij} = E(\pi_{ij}) - \mathrm{RP}_{ij}, \tag{2}$$

where CE_{ij} is the producers' anticipated certainty equivalent (\$ acre^{-1}); and RP_{ij} is the producer's risk premium (\$ acre^{-1}). If a producer is risk-neutral, risk premium is zero and the maximum the CE (equation 2) is equal to maximum net returns (equation 1).

Previous research on the effects of risk on optimal N rates for cotton under various cover crop and tillage practices incorporate yield variance in the economic framework, but do not consider the effects of the third moment, skewness (or downside risk) (Jaenicke, Frechette, and Larson, 2003; Larson et al., 2001a). Antle (1987) suggested an empirical model that included variance and skewness into risk analysis. Applying Antle's (1987) approach to determine optimal N rates for cotton production under various cover crop and tillage systems is a novel application of this model and extends our knowledge on the effectiveness of using cover crops and no-tillage for managing production risk.

Following Antle (1987), the risk premium was calculated considering the variance and skewness of the distribution of expected net returns, $f(\pi_{ij}, \varepsilon_{ij})$, where ε_{ij} is a random error. Higher order moments of the net returns distribution are the variance, $\varepsilon_{ij}^2(\pi_{ij}) = E\{[f(\pi_{ij}, \varepsilon_{ij}) - E(\pi_{ij})]^2\}$, and skewness $\varepsilon_{ij}^3(\pi_{ij}) = E\{[f(\pi_{ij}, \varepsilon_{ij}) - E(\pi_{ij})]^3\}$. A power utility function was used to characterize cotton producer risk preferences, which has been used in the literature to simultaneously consider variance and skewness in calculating risk premiums (Di

Falco and Chavas, 2006, 2009). The power utility function exhibits decreasing absolute risk aversion, and is expressed as

$$(3) \qquad U\left(\pi_{ij}\right) = \frac{\pi_{ij}^{\;1-r}}{1-r} \;.$$

This form of utility is favorable because its third differentiation (with respect to net returns) implies aversion to downside risk ($\partial^3 U/\partial^3 \pi_{ij} > 0$) (Menezes, Geiss, and Tressler, 1980). Following Antle (1987), the producer's risk premium is derived from the power utility function using a third degree Taylor series expansion:

$$(4) \qquad \mathrm{RP}_{ij} = \frac{\delta_{1ij}\varepsilon^2\left(\pi_{ij}\right)}{2} + \frac{\delta_{2ij}\varepsilon^3\left(\pi_{ij}\right)}{6},$$

where δ_{1ij} is the Arrow-Pratt measure of absolute risk aversion coefficient, which is calculated as $\delta_{1ij} = -\,[\partial^2 U(\pi_{ij})/\,\partial^2\pi_{ij}]/\,[\partial U(\pi_{ij})/\,\partial\pi_{ij}] = r/\pi_{ij}$; and δ_{2ij} is the downside risk aversion coefficient, calculated as $\delta_{2ij} = -\,[\partial^3 U(\pi_{ij})/\,\partial^3\pi_{ij}]/\,[\partial U(\pi_{ij})/\,\partial\pi_{ij}] = -\,(r^2 - r)/\pi_{ij}^{\,2}$ (Di Falco and Chavas, 2006, 2009). The Arrow-Pratt and downside risk aversion coefficient characterizes the producer's aversion to variance and skewness, respectively (Antle, 1987). Equation (4) indicates that the risk premium will increase for an increase in variance or a decrease in skewness (increase in downside risk).

Optimal N rates were determined for each combination of the winter cover crop and tillage systems at different risk preferences levels, $N_{ij}^*(r)$. As suggested in previous studies (Di Falco and Chavas, 2006; 2009; Finger, 2013), optimal N application rates, $N_{ij}^*(r)$, were calculated for risk preference levels of r = 0, r = 1, r = 2, and r = 3, where r = 0 represents a risk-neutral producer, r = 1 represents a somewhat risk-averse producer, r = 2 represents a fairly risk-averse producer, and r = 3 represents a very risk-averse producer (Anderson and Dillon, 1992).

Once optimal N rates were determined for the cover crop and tillage systems at each risk preference level, optimal CEs, $CE_{ij}^{*}(r)$, were calculated by revising equation (2) with optimal N rates. For a given risk preference level, a producer would choose the cover crop and tillage system with the highest CE. For example, a producer with a given risk preference would prefer to use a cover crop under no-tillage if the CE was higher than the CE obtained without a winter cover crop under no-tillage. Therefore, we can determine risk efficient cover crop and tillage systems at different risk preference levels while considering skewness.

Holding tillage and risk preference levels constant, the difference between the optimal CE of not planting a cover crop and the optimal CE for planting a cover crop, indicates the cost-share or incentive payment required to plant a cover crop. A positive amount indicates the value of the incentive required to encourage the adoption of cover crops. A negative value indicates that the producer does not require an incentive to adopt the cover crops.

The cost-share or incentive payment can be calculated at all three risk preference levels. The cost of planting cover crop does not change with a change in the risk preference level. Therefore, the change in the incentive payment over the different risk preference levels can provide insight into how risk preference impacts incentive payments for cover crop and no-tillage adoption. For example, if the incentive payment required to encourage a producer to adopt cover crops increases as risk aversion increases, adoption may require a higher payment to compensate for the additional risk associated with this practice. However, if the incentive payment and risk-aversion are negatively correlated, smaller payments would be required due to a positive value attached to managing risk. Similarly, incentive payments for adopting no-tillage could be calculated by subtracting the optimal CE for associated with no-tillage from the optimal CE of using conventional tillage for all cover crop species at each risk preference level.

Econometric Analysis

The first three moments of net returns distributions were estimated as a function of the N application rate. This study assumes a quadratic relationship between mean returns and N, and a linear relationship between both the variance and skewness of returns and the N application rate, which are similar to previous studies (Boyer et al., 2015; Di Falco and Chavas, 2006). Expected net returns were estimated as

$$(5) \qquad NR_{ijkt} = a_0 + a_1 N_{ijkt} + a_2 N_{ijkt}^2 + \varepsilon_{ijkt},$$

where NR_{ijkt} are the net returns (\$ acre^{-1}) for the kth (k = 1,…,4) N fertilizer rate in time t (t = 1,…,29); a_0, a_1, and a_2 are the parameters; N_{ijkt} is the N application rate; and $\varepsilon_{ijkt} \sim \left(0, \sigma_{\varepsilon_{ijkt}}^2\right)$ is an independent and identically distributed error term. Squaring the residuals of equation (5), we obtain the variance equation:

$$(6) \qquad \hat{\varepsilon}^2\left(\pi_{ijkt}\right) = \beta_0 + \beta_1 N_{ijkt} + \tau_{ijkt},$$

where β_0 and β_1 are parameters for the variance equation; and $\tau_{ijkt} \sim \left(0, \sigma_{\tau_{ijkt}}^2\right)$ is an independent and identically distributed error term. Similarly, the cube of the residuals from equation (5) is the dependent variable of the skewness response to N:

$$(7) \qquad \hat{\varepsilon}^3\left(\pi_{ijkt}\right) = c_0 + c_1 N_{ijkt} + v_{ijkt},$$

where c_0 and c_1 are parameters; and $v_{ijkt} \sim \left(0, \sigma^2_{v_{ijkt}}\right)$ is an independent and identically distributed error term.

Feasible Generalized Least Squares (FGLS) was used to obtain unbiased and efficient parameter estimates of the mean, variance, and skewness response to applied N rates (Boyer et al., 2015; Di Falco and Chavas, 2009). The FGLS approach corrects for heteroskedasticity by reweighting the variance of equations (5-7) to downweight the influence of outliers (Wooldridge, 2013).

In this study, we held prices constant. Any changes in the variance or skewness of net returns across N rates (equations 6 and 7) are therefore due to variation in cotton yields. Previous literature suggests that N fertilizer is a risk-increasing input (Babcock and Blackmer, 1992; Boyer et al., 2015; Larson et al., 2001a). Similarly, researchers have found that increasing N fertilizer rates increased downside risk (Boyer et al., 2015; Di Falco and Chavas, 2006; Finger, 2013). Thus, we hypothesize the slope of equation (6) will be positive, and the slope of equation (7) will be negative.

Data

Data on cotton lint yield response to N from 1981 to 2012 were obtained from a tillage and cover crop experiment at the University of Tennessee Experiment Station in Jackson, TN (35.63°N; 88.85°W). Cotton was grown on a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapluadalf). In the experiment, N fertilizer, cover crop species, and tillage practice were varied. Plots were arranged in a randomized complete block design with split-split-plots and four replications per year. Elemental N fertilizer was broadcast to the main plots in the form of ammonium nitrate (34-0-0) at planting at rates of 0, 30, 60, and 90 lbs acre^{-1}. The main plots were split into cover crop plots that were randomly assigned a winter wheat, hairy vetch, crimson clover, or no cover crop (fallow) treatment. The split plots were split once again and received either a no-tillage or conventional tillage (referred to hereafter as tillage) treatment. The same N fertilization rate, cover crop, and tillage treatment were applied to the same plots each year.

In each plot cotton was planted from early to mid-May after cover crops and winter weeds were terminated. Under no-tillage production a burn-down herbicide was used to kill the winter cover crop before planting cotton, whereas the tillage plots were disked twice to incorporate the cover crop before planting. Non-yield limiting levels of phosphorus and potassium fertilizer were determined through soil sampling, and these nutrients were broadcast on all plots following University of Tennessee nutrient recommendations for cotton production (Savoy and Joines, 2013). Cotton production guidelines recommended by the Tennessee Agricultural Extension Service (2001) were used for all other production practices.

Seedcotton was harvested from the two interior rows of each plot. Lint yields were determined using a lint percentage conversion rate after ginning. Increasing trends in yield over time may have occurred due to changes in management practices or improved technology. Therefore, cotton lint yields were tested for a deterministic time trend using a quadratic time response function. A time trend was present in the data and was corrected for using the M estimator (Huber, 1973), an accepted approach to adjust for the effects of time trends in yield (Boyer et al., 2015; Harri et al., 2011; Woodard et al., 2011) (Table 1). After cotton was harvested each season the winter cover crops were re-established using a seed drill at seeding rates of 90 lb acre^{-1} for wheat, 20 lb acre^{-1} for hairy vetch, and 15 lb acre^{-1} for crimson clover. Individual plots were 29 by 13 feet, each with four rows.

<<<<INSERT TABLE 1 APPROXIMATELY HERE>>>>

Average annual prices of N (\$ lb^{-1}) and cotton lint (\$ lb^{-1}) from 1984 to 2012 were used in a partial budget to calculate the expected net returns. Nominal prices were converted to reflect real 2012 prices using the Federal Reserve implicit price deflator (U.S. Bureau of Economic Analysis, 2015). From 1984 to 2012, the average annual real N price was \$0.49 lb^{-1} (USDA Economic Research Service (USDA-ERS), 2013), and the average annual real cotton lint price was \$0.83 lb^{-1} (USDA-ERS, 2014). Production costs for each combination of cover crop and tillage system can be separated into the cost of establishing a cover crop and the production costs associated with preparing the field using tillage or no-tillage practices. From 2006 to 2012, the real average price of cover crop seed was \$0.27 lb^{-1} for winter wheat, \$1.86 lb^{-1} for hairy vetch, and \$1.40 lb^{-1} for crimson clover. These costs were obtained from the Tennessee Farmers Cooperative. The cost of planting the cover crops using a no-tillage planter was \$15.27 acre^{-1} (University of Tennessee Agricultural and Resource Economics Department, 2016). The cost of destroying a cover crop for no-tillage included the cost of a burn-down herbicide application and the chemicals, which was approximately \$17.98 acre^{-1} (University of Tennessee Agricultural and Resource Economics Department, 2016). For tillage, the cost of preparing the seedbed for planting was \$33.66 acre^{-1} (University of Tennessee Agricultural and Resource Economics Department, 2016).

Results

Parameter Estimates

Expected net returns for tillage cotton after crimson clover did not respond to N application (Table 2). Parameter estimates for the mean net return of all other cover crop and tillage system mean net return were significant with the expected signs. The positive linear and negative quadratic estimates suggest diminishing marginal returns to N fertilizer.

<<<<INSERT TABLE 2 APPROXIMATELY HERE>>>>

Intercepts of the all estimated variance equations were positive and significant. Under both tillage systems, the variance of net returns increased with increasing N application rates for cotton after no cover and winter wheat cover crops ($P < 0.01$) as well as the variance of net returns for no-tillage cotton following hairy vetch increased as N fertilizer rates increased ($P < 0.10$). N application did not have a significant effect on the variance of net returns for crimson clover under either tillage system or tillage cotton after hairy vetch.

Estimated slopes for the skewness equations had the hypothesized negative sign. Regardless of the tillage system, the skewness of net returns for cotton following no cover or winter wheat decreased with increasing N application rates ($P < 0.10$), implying that exposure to downside risk increased as the N application rate increased. Slope estimates were not significant for hairy vetch or crimson clover cover crops, but their intercepts were significant. Thus, net returns for cotton grown after hairy vetch or crimson clover were negatively skewed, but skewness was unaffected by the N application rate.

Optimal N and Cotton Yield

Tillage cotton following a winter cover crop reduced the optimal N rate relative to no cover for all risk preference levels (Table 3). The optimal N rate for cotton after crimson clover was zero, indicating that the legume cover crop was able to capture enough N into the soil to meet the N needs for the cotton. Optimal N fertilizer rates decreased as risk aversion increased for cotton after no cover or winter wheat, indicating N fertilizer is a risk-increasing input. However, producer risk preferences had no effect on optimal N for cotton after hairy vetch and crimson clover under tillage. For all risk preference levels, optimal tillage lint yields were highest for cotton after no cover crop, followed by hairy vetch, winter wheat, and crimson clover. Thus, cost savings from N fertilizer application from the cover crops would have to be greater than the cost of the cover crop and yield losses to be more profitable than no cover crop.

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Legume cover crops reduced the optimal N rates relative to cotton after no cover crop with no-tillage, but optimal N rates for cotton after winter wheat were higher than no cover crop with no-tillage. Optimal N rates for cotton after no cover crop, hairy vetch, and winter wheat decreased as risk-aversion increased. Optimal N rates for cotton after crimson clover were not affected by producer risk preferences. For no-tillage, the highest optimal yields were realized for cotton after winter wheat, followed by hairy vetch, no cover, and crimson clover.

Optimal N rates and lint yields were lower for no-tillage cotton following no cover and hairy vetch than under tillage. Conversely, optimal N rates and yields under no-tillage were higher for cotton following winter wheat and crimson clover than under tillage. Overall, expected lint yield was greatest for tillage cotton following no cover crop.

Certainty Equivalents

Tillage cotton after no cover crop maximized CE for risk-neutral (r = 0) to fairly risk-averse (r = 2) preferences (Table 4). However, no-tillage cotton following no winter cover is risk efficient for producers with very risk-averse preferences (r = 3). Using a cover crop produced a lower CE than no cover for both no-tillage and tillage. The finding of an unfavorable risk and return tradeoff with cover crops is consistent with data indicating limited adoption of cover crops in Mid-South crop production (Wade, Claassen, and Wallender, 2015). Without financial assistance, producers could achieve a higher guaranteed return by not planting a winter cover crop. Of the cover crops examined in this study, we can conclude that hairy vetch would be the preferred cover crop under tillage for all risk-preference levels and winter wheat would be the preferred cover crop under no-tillage for all risk-preference levels.

<<<<INSERT TABLE 4 APPROXIMATELY HERE>>>>

Incentive payments required to adopt a cover crop based upon producer risk preferences were calculated using differences in CEs for a cover crop versus no cover crop (Table 5). For tillage, the lowest incentive payment required by a risk-neutral producer to plant a cover crop was \$60 acre^{-1} for hairy vetch (\$731 - \$671 = \$60 acre^{-1}) and the highest payment was \$115 acre^{-1} for crimson clover (\$731 - \$616 = \$115 acre^{-1}). As a producer becomes more risk-averse, the incentive payment to plant a cover crop decreases for tillage cotton. The producer’s willingness to pay to decrease risk exposure (i.e., risk premium) is smaller when cover crops were planted than when no cover crop was planted, meaning the producer can pay less to reduce risk with cover crops and tillage. Therefore, planting crop covers provide risk-averse producers with an added risk-reduction benefit under tillage, reducing their required compensation to adopt cover crops.

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On the other hand, the incentive payment for adopting a cover crop under no-tillage rose with risk-aversion preferences. Incentive payments increased by \$7 acre^{-1} for hairy vetch, \$2 acre^{-1} for winter wheat, and \$4 acre^{-1} for crimson clover for risk-neutral to very risk-averse producers. Risk premiums under no-tillage are higher with a cover crop than without a cover crop, which means producers would have to pay more to reduce risk exposure with cover crops and no-tillage. Planting cover crops in no-tillage production therefore may increase risk exposure, and a producer would require a higher incentive payment to be compensate for the added risk. Including cover crops with no-tillage may not provide a favorable risk and return tradeoff to offset the additional costs of the cover crops. Overall, incentive payments were lower to encourage producers to use cover crops for no-tillage cotton relative to tillage cotton. However, the environmental benefits from using cover crops would likely be larger when combined with tillage rather than no-tillage.

Incentive payments encouraging the adoption of no-tillage were only required when a producer did not use a cover crop (Table 6). A risk-neutral producer would require a payment of \$28 acre^{-1} (\$731 - \$703 = \$28 acre^{-1}) to switch from tillage to no-tillage. As the risk-aversion level increased, the incentive payment decreased, becoming negative with very risk-averse preferences. A negative incentive payment indicates no-tillage is optimal without an incentive payment when no cover crop was planted. As risk aversion increases, producers can reduce risk exposure cheaper with no-tillage than with tillage when no cover crop was planted. Thus, the results suggest that risk-averse producers receive some positive risk-reduction benefit with no-tillage relative to tillage. Given the risk and return tradeoffs estimated from the long-term experiment, the incentive payments for cover crops also appear to encourage the adoption of no-tillage. Incentive payments that could adoption of these practices do appear to vary by risk preference. Agencies encouraging the adoption of these conservation practices could consider these risk and return tradeoffs in determining cost-share payments in cotton production.

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Conclusion

The objective of this research was to determine the effect of risk on incentive payments encouraging producers to implement cover crops and tillage in cotton production. Additionally, we evaluated the effects of downside risk on optimal N application rate in combination with tillage and cover crop decisions. Data on cotton lint yield response to N fertilizer were obtained from a long term-tillage and winter cover crop experiment in Jackson, Tennessee. Expected net returns were calculated using partial budgeting, and downside risk was introduced into the producer's optimal N application decision. This study provides information on how risk impacts a producer's optimal cover crop, tillage, and N application decisions. Moreover, the results of this study can better inform agencies on the cost share payments that would be required to switch to no-till and cover crops for southeastern cotton production.

Under tillage, using winter cover crops reduced the optimal N rate relative to no winter cover at all risk preference levels. Under no-tillage, legume cover crops reduced the optimal N rates relative to cotton after no cover crop, while optimal N rates for cotton after winter wheat were higher than no cover crop. A risk-neutral to fairly risk-averse producer maximized CEs by not using a cover crop and using tillage. Very risk-averse producers preferred no-tillage cotton following no winter cover.

A key conclusion from these results is that risk preferences can impact the incentive payment required to encourage adoption no-tillage and cover crops. This result has implications in improving incentive payments structures to adopt these conservation practices. However, the data used in this study consisted of only single species cover crops; therefore, our results do not consider any additional benefits or costs associated with multiple species cover crops. Future research should consider the effects of mixed species cover crops on estimated incentive payments. In addition, future research valuing the risk management benefits a producer receives from using cover crops with a survey would provide an interesting comparison to the findings of this study.

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Table 1. Average Cotton Lint Yields (lb acre^{-1}) by Winter Cover Crop, Tillage System, and N Application Rate from 1984 to 2012

N Rate	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover
		till		
0	725	662	856	814
30	849	822	942	861
60	928	914	919	821
90	974	887	893	926
		No-Till		
0	614	619	866	838
30	798	826	937	899
60	923	927	903	904
90	885	925	843	892

Table 2. Parameter Estimates of the Mean, Variance, and Skewness Regression Equations by Winter Cover Crop and Tillage System

	Till				No-Till			
Parameter[a]	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover
					Mean			
Intercept (a_0)	602.0***	548.0***	716.5***	685.4***	505.9***	514.2***	722.6***	696.9***
Slope (a_1)	3.415***	5.437***	2.053**	-0.753	6.577***	6.653***	2.012**	1.532*
Quadratic (a_2)	-0.018**	-0.042***	-0.026**	0.012	-0.049***	-0.048***	-0.031***	-0.017*
					Variance			
Intercept (β_0)	38,022***	22,555***	44,425***	42,178***	28,809***	24,422***	44,155***	42,724***
Slope (β_1)	187.66***	291.94***	64.53	117.36	228.83***	230.80***	153.70*	117.67
					Skewness			
Intercept (c_0)	2,189,104	-1,658,473	-4,291,665*	-3,420,733*	-1,055,276	-414,126	-3,939,726*	-5,841,971***
Slope (c_1)	-127,356**	-55,022*	-31,462	-43,422	-100,012***	-117,996***	-55,850	-25,888

***,**,* denote significance at the 1%, 5%, and 10% levels.

[a] Parameter estimates were corrected for heteroscedasticity using Feasible Generalized Least Squares.

Table 3. Optimal Nitrogen Application (lb acre^{-1}) and Lint Yield (lb acre^{-1}) by Winter Cover Crop and Tillage System

	Till				No-Till			
Risk Level[a]	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover
				Optimal Nitrogen Rate[b]				
$r = 0$	95	65	39	0	66	69	32	45
$r = 1$	89	62	39	0	65	67	31	45
$r = 2$	83	59	39	0	62	64	29	45
$r = 3$	75	55	39	0	59	61	28	45
				Cotton Lint Yield				
$r = 0$	977	910	935	826	915	938	929	908
$r = 1$	973	908	935	826	913	936	928	908
$r = 2$	967	905	935	826	911	933	927	908
$r = 3$	957	900	935	826	906	929	926	908

[a] $r = 0$ represents a risk-neutral producer, $r = 1$ represents a somewhat risk-averse producer, $r = 2$ represents a fairly risk-averse producer, and $r = 3$ represents a very risk-averse producer.

[b] The price of cotton was assumed to be \$0.83 lb^{-1} and the price of N was assumed to be \$0.49 lb^{-1}.

Table 4. Expected Returns, Certainty Equivalent, and Risk Premium ($ acre^{-1}) by Winter Cover Crop and Tillage System

	Till				No-Till			
Risk Level[a]	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover
				Net Returns[b]				
r = 0	731	652	671	616	703	682	679	671
r = 1	731	651	671	616	702	681	679	671
r = 2	729	650	671	616	701	680	679	671
r = 3	724	648	671	616	699	678	679	671
				Certainty Equivalent				
r = 0	731	652	671	616	703	682	679	671
r = 1	686	618	635	579	667	647	640	635
r = 2	635	582	596	539	628	606	598	595
r = 3	580	544	553	495	585	562	554	550
				Risk Premium				
r = 0	0	0	0	0	0	0	0	0
r = 1	45	34	36	37	35	35	39	36
r = 2	93	69	76	77	74	74	80	77
r = 3	145	104	118	121	115	116	124	121

[a] *r* = 0 represents a risk-neutral producer, *r* = 1 represents a somewhat risk-averse producer, *r* = 2 represents a fairly risk-averse producer, and *r* = 3 represents a very risk-averse producer.

[b] The price of cotton was assumed to be $0.83 lb^{-1} and the price of N was assumed to be $0.49 lb^{-1}.

Table 5. Estimated Incentive Payments (\$ acre^{-1}) to Planting Winter Cover Crop by Tillage System

	Till			No-Till		
Risk Level[a]	Winter Wheat	Hairy Vetch	Crimson Clover	Winter Wheat	Hairy Vetch	Crimson Clover
$r = 0$	79[b]	60	115	21[c]	24	32
$r = 1$	68	51	107	20	27	32
$r = 2$	54	39	97	22	30	33
$r = 3$	36	26	84	23	31	35

[a] $r = 0$ represents a risk-neutral producer, $r = 1$ represents a somewhat risk-averse producer, $r = 2$ represents a fairly risk-averse producer, and $r = 3$ represents a very risk-averse producer.
[b] Payments were calculated as the difference in the certainty equivalent of conventional till with no cover crop and the certainty equivalent for each of the cover crops under till.
[c] Payment were calculated as the difference in the certainty equivalent of no-till with no cover crop and the certainty equivalent for each of the cover crops under no-till.

Table 6. Estimated Incentive Payments ($ acre^{-1}) to Producers for No-Till Production by Cover Crops

Risk Level[a]	No Cover	Winter Wheat	Hairy Vetch	Crimson Clover
$r = 0$	28[b]	-30	-7	-55
$r = 1$	21	-29	-5	-56
$r = 2$	10	-25	-2	-56
$r = 3$	-1	-18	-1	-55

[a] $r = 0$ represents a risk-neutral producer, $r = 1$ represents a somewhat risk-averse producer, $r = 2$ represents a fairly risk-averse producer, and $r = 3$ represents a very risk-averse producer.
[b] Payments were calculated as the difference in the certainty equivalent of till with a given cover crop and the certainty equivalent for no-till with the corresponding cover crop.