Investment Analysis of Long-Term Cover Crops and Tillage Systems on Cotton Production

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Abstract

Upland cotton fields have minimal amounts of soil surface crop residue after-harvest, exposing soil and increasing the risk of erosion. This is especially challenging in the Mid-South United States where cotton is commonly grown on soils, naturally prone to soil erosion. Winter cover crops and no-till planting are two practices that can mitigate soil erosion by increasing soil surface biomass, but there is uncertainty on how these practices can impact producer profits and risk. The objective of this study was to determine the profitability and risk of three winter cover crop (no cover crop, winter wheat, and hairy vetch) treatments and two tillage (no-till and till) treatments in cotton production. Simulation models were developed to generate net present value (NPV) distributions of investing into the long-term use of cover crop and tillage systems. Data were collected from a 29-year cotton nitrogen (N) fertilizer, tillage, and cover crop experiment in West Tennessee. Profit-maximizing N rate and yields varied across cover crop and tillage combinations. Risk neutral, profit-maximizing producers would prefer till planting and not planting a cover crop. Risk averse producers prefer no-till planting with no cover crops. These results indicate that no-till planting can reduce cotton producers' exposure to risk. The NPV approach and the long-term dataset provides unique insight into the economic benefits from investing into continuous cover crop and no-till systems in cotton production.

Key Words: Cotton, Cover crops, Net Present Value, Tillage, Simulation

Introduction

A global challenge associated with crop production is minimizing water-induced soil erosion without reducing producer profits. This challenge is especially difficult for upland cotton (*Gossypium hirsutum* L.) production because low amounts of soil surface crop residue remains on the fields post-harvest, leaving more soil exposed and increasing the susceptibility to water-induced soil erosion (Nyakatawa et al., 2001; United States Department of Agriculture Economic Research Service (USDA ERS), 2012). Furthermore, cotton is produced in the Mid-South United States on sandy or silty soils, which are more vulnerable to soil erosion (Bradley and Tyler, 1996; Boquet et al., 2004). Researchers and producers, in this region, have been long-interested in evaluating practices that could reduce soil erosion without reducing producer profits (Snapp et al., 2005; Triplett and Dick, 2008).

Winter cover crops and no-tillage (no-till) planting are two practices that can mitigate soil erosion by increasing soil surface biomass. Studies demonstrate that these practices can increase organic matter and nutrients in soils, improve soil moisture holding capacity, reduce soil water evaporation, and mitigate water-induced soil erosion (Snapp et al., 2005; Triplett and Dick, 2008; Richter et al., 2007; Karlen et al., 2013; Mbuthia et al., 2015). Despite the environmental and agronomic benefits of using winter cover crops and no-till planting, producer implementation of these practices is low across the United States (Bergtold et al., 2012; Boyer et al., 2014; Dunn et al., 2016; Ma et al., 2011; Wade et al., 2015). Less than 2% of all United States cropland (2.75 million ha) was planted with winter cover crops during 2010-2011, and no-till planting was reported on 36 million ha (40%) of United States cropland in 2010-2011 (Wade et al., 2015).

Inconsistent findings on the profitability of planting cover crops and no-till may explain slow adoption rates (Boquet et al., 2004; Dunn et al., 2016; Snapp et al., 2005; Triplett and Dick, 2008). Cover crops could increase producer net returns through higher yields and reduced nitrogen (N) fertilizer costs with N fixating cover crop species, but establishment and termination of the cover crop increase costs. No-till planting may have lower machinery and fuel costs but it may increase chemical costs compared to conventional tillage. For cotton production, net returns from planting cover crops are mixed (Varco et al., 1999; Larson et al., 2001; Hanks and Martin, 2007; Foote et al., 2014). No-till planting may decrease machinery and fuel costs but can increase chemical costs compared to till planting. Increases in crop yields drive the profitability of no-till planting because production costs of the two tillage systems are often similar (Triplett and Dick, 2008). Similarly for cover crops, differences in net returns to no-till and till planting have varied across studies (Hank and Martin, 2007; Triplett and Dick, 2008).

Surveys suggest that producers are reluctant to use cover crops and no-till because of the perceived risk that these practices decrease yields (Arbuckle Jr. and Roesch-McNally, 2015; Baumgart-Gertz et al., 2012; Reimer et al., 2012). Larson et al. (2001) used experiment plot data to evaluate the risk associated with cover crops and no-till in cotton production. They found both risk-neutral and risk-averse producers preferred till planting with no cover crop over using no-till and a cover crop. Thus, no-till provided no risk management benefits over till planting. However, a recent study by Allen and Borchers (2016) found that land rental rates for no-till land were higher than till land. They concluded that soils under no-till production may reduce yield variability or production risk, making the land more valuable for producers. Conclusions on risk management benefits associated with cover crops and no-till are also mixed.

Soule et al. (2000) postulated that long-term continuous use of conservation practices such as cover crops and no-till may increase profits and reduce production risk. Long-term cover crop and no-till studies have shown the benefits of these practices on soils and yields are accumulated over many years of continuous use (Richter et al., 2007; Karlen et al., 2013; Mbuthia et al., 2015). However, studies that have evaluated the effects of cover crops and no-till on expected annual profitability and risk have used yield data from relatively short-term experiments. Additionally, studies have determined optimal cover crop and tillage systems using expected annual profit rather than treating the decision problem as a long-term investment decision. Thus, the producer's decision to use cover crops and no-till is based on maximizing the present value of net returns over a planning horizon instead of maximizing expected annual profit. Analyzing the profitability and risk of cover crops and no-till as a long-term investment decision using yield data from a long-term experiment would make a unique contribution to the literature.

The objective of this research was to determine the profitability and risk of alternative winter cover crop (no cover crop, hairy vetch, and winter wheat) and tillage (no-till and till) practices in cotton production. Simulation models were developed to generate distributions of net present value (NPV) for each production system. These distributions were compared to determine the optimal production system based on different levels of risk aversion. Data are from a 29-year (1984-2012) continuous cotton N, tillage, and cover crop experiment in West Tennessee.

Economic Framework

Economic studies have analyzed the profitability and risk of cover crops and no-till using expected annual profit and deviations from expected annual profit (risk) criteria (Hanks and Martin, 2007; Foote et al., 2014; Jaenicke et al., 2003; Larson et al., 2001; Varco et al., 1999). The expected annual profit criterion provides insight into economic benefits such as lower N costs and machinery costs. However, producers may consider cover crops and no-till practices to be a long-term investment where recurring benefits to soils and crop yields are uncertain and compounded over a number of years. Thus, cover crop and no-till practices may generate lower initial profits than till planting with no cover crop but the present value of profits over a longer term planning horizon may be greater than with no-till and winter cover crop practices. A possible explanation of why studies did not consider the present value of profits may be due to the use of data from short-term experiments.

Our unique approach analyzes the profitability and risk of several combinations of cover crop and till practices in cotton production using NPV calculated over a 29-year planning horizon. The use of cover crop and tillage systems over a long-term investment period is

(1) $$V_{jk} = \sum_{t=1}^{T} \frac{NR_{jkt}}{(1+R)^t},$$

where V_{jk} is the NPV (\$ ha^{-1}) of the using cover crop j (j = 1,…, J) and tillage system k (k = 1,…, K); NR_{jkt} is the annual net returns (\$ ha^{-1}) in time period t (t = 1,…, T); and R is the risk-adjusted discount rate.

Partial budgeting was used to calculate the net returns to each cover crop and tillage system. Machinery, chemical, and cover crop seed costs vary across these production systems along with the optimal N fertilizer rates. Reduction in the cost of N fertilizer resulting from using a legume cover crop is also an important factor in determining the profitability of covers crops (Larson et al., 2001). Annual net returns (NR) are:

(2) $$NR_{jkt} = p^C y_{jkt}(N) - p^N N_{jkt} - WC_j - T_k,$$

where p^C is the cotton lint price (\$ kg^{-1}); $y_{jkt}(N)$ is the cotton lint yield (kg ha^{-1}) and is a function of N fertilizer; p^N is the price of N fertilizer (\$ kg^{-1}); N_{jkt} is the N fertilizer rate (kg ha^{-1}); WC_j are expenses associated with cover crop including seed, machinery, labor, and interest (\$ ha^{-1}); and T_k is the cost of the tillage method (\$ ha^{-1}).

A profit-maximizing, risk-neutral cotton producer would select the cover crop and tillage combination with the highest expected NPV. However, a risk averse producer would prefer cover crop and tillage practices that maximizes the expected utility $U(V_{jk}, \lambda)$, where λ is the producer's risk preference level. Depending on a producer's risk preference level, some producers are willing to exchange higher net returns for lower variability in net returns (i.e., risk exposure).

Economic Modeling

We model the producer's decision to use alternative cover crop (hairy vetch, no cover, or winter wheat) and tillage (till and no-till) combinations as a function of net returns and risk. Lint yield response to N was estimated for each of the cover crop and tillage combination. The response functions were used to determine profit-maximizing N rates, lint yields, and net returns for each practice combination in each year. Optimal net returns were subsequently substituted into the NPV equation to simulate market risk (i.e., variation in prices) and production risk (i.e., variation in yields) effects on the practice decision. NPV was simulated for each cover crop and tillage combination. A risk analysis was conducted based on these simulated distributions. Details of these steps are discussed below.

Statistical Analysis

Cotton lint yield response to N fertilizer are commonly estimated following a quadratic functional form (Bauer and Roof, 2004; Bronson et al., 2001; Cochran et al., 2007; Larson et al., 2001). The functional form assumes diminishing marginal yield productivity as N applied increases and attains a yield maximum with yields declining thereafter. There have been numerous genetic improvement made to cotton and other row crops over last decade, which have increased yields (Boyer et al., 2015; Finger, 2010; Sherrick et al., 2004; Swinton and King, 1991). Additionally, the accumulated effects of cover crops and no-till on soil health can increase yields over time. Time trend variables in yield response functions are commonly used to capture how yields change over time due to advances in technology (Boyer et al., 2015; Finger, 2010; Sherrick et al., 2004; Swinton and King, 1991). However, the appropriate time trend structure in the yield functions is debated. Just and Weninger (1999) suggested testing down from higher order polynomials of time trend variable until an appropriate structure is found. We follow this approach and estimate lint yield response to N following a quadratic functional form and include linear, quadratic, and cubic time trend variables for each of the cover crop and tillage combination, which is specific as

(3) $$y_{jkt} = \beta_{0jk} + \beta_{1jk}t + \beta_{2jk}t^2 + \beta_{3jk}t^3 + \beta_{4jk}N + \beta_{5jk}N^2 + \beta_{6jk}N \times t + e_{jkt},$$

where $\beta_0,\ldots,\beta_6$ are coefficients to be estimated; and $e_{jkt}{\sim}(0,\sigma_e^2)$ is an independent and identically distributed random error term. The yield response model was estimated using M-estimation with the ROBUSTREG procedure in SAS 9.2.1 (SAS Institute, Inc., Cary, NC). The M-estimation method was developed by Huber (1973) and uses maximum likelihood to reweight the residuals so outliers receive less weight than with ordinary least squares. This regression approach has been used to estimated yield response to an input in conjunction with time trend variables (Woodard and Sherrick, 2011).

The estimated yield response function (Eq. [3]) is substituted into the net returns equation (Eq. [2]) for each cover crop and tillage combination to find the profit-maximizing N rate, yield, and net returns by taking the first order conditions of the function with respect to N. The first-order condition is set equal to zero and solved for N as

$$(4) \qquad N_{jkt}^{*} = \left(\frac{p^{N}}{p^{C}} - \beta_{4jk} - \beta_{6jk}t\right)/(2\beta_{5jk}),$$

where N_{jkt}^{*} is the profit-maximizing N rate in a given year. The profit-maximizing N rate is a function of N and cotton prices, yield response to N, and year. The profit-maximizing yields in a given year were found by substituting N_{jkt}^{*} into the yield response function (Eq. [3]), and profit-maximizing net return in a given year were calculated by substituting N_{jkt}^{*} and the profit-maximizing yield into the net return function (Eq. [2]).

Simulation and Risk Analysis

Eq. [4] shows that price and yield variability are important components in determining the optimal N rate, yield, and net returns in a given year. Monte Carlo methods were used to simulate NPV while considering the variability of prices and yield. Price uncertainty for cotton lint, N fertilizer, and cover crop seed were introduced into the model by bootstrapping the observed real average annual lint and nitrogen prices. Yield variability was introduced into the model by assuming the coefficients of the yield response function were stochastic. The yield response coefficients were drawn from the multivariate normal (MVN) distribution random variables:

$$(5) \quad \begin{bmatrix} \beta_{0jk}^{*} \\ \vdots \\ \beta_{6jk}^{*} \end{bmatrix} \sim MVN\left(\left[\begin{pmatrix} \beta_{0jk} \\ \vdots \\ \beta_{6jk} \end{pmatrix} \right], \begin{bmatrix} \sigma_{\beta_{0jk}}^{2} & \cdots & \rho_{\beta_{0jk},\beta_{6jk}}\sigma_{\beta_{0jk}}\sigma_{\beta_{6jk}} \\ \vdots & \ddots & \vdots \\ \rho_{\beta_{6jk},\beta_{0jk}}\sigma_{\beta_{6jk}}\sigma_{\beta_{0jk}} & \cdots & \sigma_{\beta_{6jk}}^{2} \end{bmatrix} \right)$$

where the mean of the distribution is the vector of the estimated yield response function coefficients. The covariance matrix of coefficients was a seven-by-seven matrix where ρ is the correlation coefficient. The "*" denotes a randomly drawn coefficient for each draw of the simulation (Cuvaca et al., 2015). Simulation and Econometrics to Analyze Risk (SIMETAR©) was used to generate the distributions and perform the simulations (Richardson et al., 2008). A total of 5,000 net return observations were simulated for each of the cover crop and tillage combination.

Stochastic dominance criteria were used to compare average and variability of NPV for the different cover crop and tillage production systems. By first degree stochastic dominance, a production scenario with cumulative distribution function (CDF) F dominates another scenario with CDF G if $F(V) \leq G(V)\ \forall\ V$. If first degree stochastic dominance is not sufficient, second degree stochastic dominance adds the restriction that producers are risk averse, which increases the chance of finding a preferable scenario (Chavas, 2004). Second degree stochastic dominance states the scenario with CDF F dominates another scenario with CDF G if $\int F(V)dV \leq \int G(V)dV\ \forall\ V$. Stochastic dominance was also conducted in SIMETAR© (Richardson et al., 2008).

If no cover crop and tillage system is dominate according to the first and second degree stochastic dominance rules, stochastic efficiency with respect to a function (SERF) was used to rank the cover crop and tillage systems over a range of absolute risk aversion levels (Hardaker et al., 2004). SERF requires choosing a utility function, $U(\tilde{V}_{jk}, r)$, which is a function of the distribution of NPVs ($\tilde{V}_{jk}$) and absolute risk-preference level r. The utility function allows us to calculate a certainty equivalent (CE), which is the certain return an individual is willing to accept rather than taking a chance at an uncertain and potentially higher return. A rational, risk averse individual would accept a certain lower return instead of a higher uncertain return. The cover crop and tillage system with the highest CE at a given level of risk aversion is optimal that maximizes utility. We can take the difference between the CE of any two cover crop and tillage systems to calculate the utility weighted risk premium. The risk premium is the minimum amount of money an individual would need to switch from the cover crop and tillage system with the greatest CE to the alternative cover crop and tillage system with the lower CE. This calculation can interpret the CEs and compare cover crop and tillage systems. The SERF analysis was also conducted in SIMETAR© (Richardson et al., 2008).

A negative exponential utility function was used in this analysis, which specifies a absolute risk-aversion coefficient (ARAC) to calculate the CE (Pratt, 1964). The ARAC represents the ratio of derivatives of the person's utility function $r_a(r) = -U''(r)/U'(r)$. Following Hardaker et al. (2004), the lower bound ARAC was zero, meaning the producer was risk-neutral (profit-maximizer). The upper bound ARAC was found by dividing four by the average NPV for all the cover crop and tillage scenarios, which indicates extreme aversion to risk. ARAC values ranged from 0.0 for risk neutral to 0.03 for extremely risk averse.

Data

Cotton yield data were collected from a 29-year experiment (1984-2012) on winter cover crops, N fertilization, and tillage practices. The experiment was conducted at the West Tennessee Research and Education Center, Jackson, Tennessee (35.624°N, 88.845°W). The soil was classified as a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapluadalf), which is a deep, well-drained, moderately permeable soil formed in thick (1.5 m) loess deposits (USDA National Resource Conservation Service (NRCS), 2002). Soils in the Memphis series are common for cotton production in Tennessee and neighboring Mid-South states. Data collected from this experiment during 1984-2001 have used in other studies (Cochran et al., 2007; Jaenicke et al., 2003; Larson et al., 2001).

The experimental design was a randomized complete block with split-plots and four replications. N fertilization rates varied in the main plots and winter cover crop and tillage varied in the split plots. Plots were randomly assigned N fertilizer rates of 0, 34, 67, or 101 kg N ha^{-1}. Ammonium nitrate (340 g N kg^{-1}) was hand broadcasted at planting. The N plots were split vertically and randomly assigned one of the three cover crop treatments: no cover (native vegetation), winter wheat, and hairy vetch. Each cover crop plot was vertically split again and randomly assigned no-till or till treatments. Plot size for each treatment combination was 4 m wide and 9 m long. The same N application rate, winter cover crop, and tillage combinations was applied to each plot in each year of the experiment. The annual P rate was 101 kg P ha^{-1} and the annual K rate was 101 kg K ha^{-1}. Table 1 displays the average cotton yield by N fertilizer rate, cover crop, and tillage system.

<<< Insert Table 1 Approximately Here >>>

Before planting, no-till treatments received a burn-down application of generic glyphosate [*N*-(phosphonomethyl) glycine] and pyrithiobac sodium [sodium 2-chloro-6-[(4, 6-dimethoxy pyrimidin-2yl) thio] benzoate] to kill the cover crops and weeds. Cover crops and weeds were destroyed by disking till treatments twice. Cotton was planted the middle- to late-May on 17.8 cm row spacing with a population density of 9 to 10 plants m^{-2}. The same cultivar was planted on all plots in each year of the experiment and over the experiment the cultivars were ‘Stoneville 825’ from 1984 to 1993, ‘Deltapine 50’ in 1994 and 1995, ‘Stoneville 132’ in 1996; ‘Deltapine 50’ in 1997, ‘Stoneville 474’ in 1998, ‘Deltapine 425’ in 1999 and 2000, ‘Deltapine 451’ from 2001 to 2006, and ‘Phytogen’ from 2007 to 2012.

Seed cotton was mechanically harvested from the two inside rows of each plot and ginned using a 1/5-scale gin at the West Tennessee Research and Education Center (Jackson, Tennessee) to determine lint yields. Winter cover crops were re-established in late October after cotton harvest. The seeding rates were 101 kg ha^{-1} for winter wheat and 22 kg ha^{-1} for hairy vetch.

Prices used in the simulation model for cotton lint and ammonium nitrate were collected from 1984-2012 (USDA National Agricultural Statistical Service (NASS), 2016) (Table 2). All prices were adjusted to 2012 dollars using the Implicit Gross Domestic Product Price Deflator (United States Bureau of Economic Analysis, 2016). Cover crop seed prices were collected from 2006-2012 through personal communication with the Tennessee Farmer Cooperative. Cover crop seed prices were also adjusted to 2012 dollars using the Implicit Gross Domestic Product Price Deflator (United States Bureau of Economic Analysis, 2016). Machinery and labor costs were calculated using University of Tennessee Field Crop Budgets for 2015 (Smith et al., 2015). Total establishment costs for each cover crop were \$130.02 ha^{-1} for hairy vetch, and \$106.27 ha^{-1} for winter wheat. The cost of destroying a cover crop was \$47.45 ha^{-1} for no-till and \$93.17 ha^{-1} for till (Smith et al., 2015)

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

Results

Parameter Estimates

Parameter estimates for the cotton yield response to N and time by cover crop and tillage system are shown in Table 3. The parameter estimates for all the time variables were significant ($P < 0.01$) and the signs for the linear, quadratic, and cubic estimates were the same across all cover crop and tillage systems. The estimates indicate yields decreased between 1984 and 1995 in the experiment and increased thereafter. The novelty of this experiment during the early years resulted in several challenges prior to 1995. Larson et al. (2001) noted the difficulty controlling weeds prior to 1995 and Cochran et al. (2007) stated soil pH levels declined until 1995 when lime was applied. New management practices for controlling weeds and maintaining soil pH levels along with the use of glyphosate-resistant cotton resulted in higher cotton lint yields from 1995 to 2012.

<<<<INSERT TABLE 3 APPROXIMATELY HERE>>>>

Parameter estimates for cotton lint yield response to N were significant ($P < 0.01$) except for the linear estimate for no-till cotton planted with hairy vetch. The positive linear and negative quadratic estimates suggest diminishing marginal returns to N fertilizer for all cover crop and tillage systems except no-till planting with hairy vetch. Larson et al. (2001) observed lint yields following vetch were not responsive to N fertilizer under no-till using data from an earlier time period of this experiment.

Simulation Results

The average and standard deviation of simulated profit-maximizing N rate, profit-maximizing yield, and profit-maximizing NPV by cover crop and tillage system are shown in Table 4. Simulated profit-maximizing N rates were highest for till cotton with no cover crop (95 kg ha^{-1})

and lowest for no-till cotton with hairy vetch (37 kg ha^{-1}). Planting hairy vetch, which is a legume cover crop, decreased the profit-maximizing N rate for till and no-till cotton relative to no cover crop and winter wheat. Planting wheat winter increased the profit-maximizing N rate for no-till cotton relative to not planting a cover crop by 2 kg ha^{-1} but decreased the profit-maximizing N rate for till cotton relative to not planting a cover crop by 19 kg ha^{-1}. Profit-maximizing N rates were lower for no-till planting than till planting with no cover crop and hairy vetch were planted as a cover crop. However, profit-maximizing N rates were higher for no-till planting than conventional till planting with winter wheat.

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

Larson et al. (2001) found no-till planting with no cover crop to have a higher profit-maximizing N rate than till planting with no cover crop. In this analysis, the profit-maximizing N rate for till cotton with no cover crop was about 32 kg ha^{-1} lower than what Larson et al. (2001) observed. These difference indicate how continuous cover crop and no-till use over time can change profit-maximizing N rates.

Profit-maximizing yields were, on average, highest for till cotton with no cover crop (1,155 kg ha^{-1}) but the standard deviation indicates that till cotton with no cover crop had the most production risk. The lowest profit-maximizing yield was no-till planting with no cover crop (1,082 kg ha^{-1}). Thus, planting a cover crop increased profit-maximizing yields with no-till but decreased profit-maximizing yields with till. For both no-till and till, cotton planted after winter wheat had a higher profit-maximizing yield than cotton planted after hairy vetch. Planting a cover crop decreased production risk with till planting, suggesting that cover crops can reduce production risk under till planting. However, the impact of cover crops on production risk under no-till planting ambiguous, since hairy vetch increased production risk and winter wheat decreased production risk with no-till planting.

Till with no cover had the highest expected NPV of \$26,815 ha^{-1}. Thus, a profit-maximizing producer would prefer a till planting with no cover crop system. This is consistent with what Larson et al. (2001) found for annual net returns. However, this cover crop and tillage system has the second highest variability in NPV. No-till planting with no cover crop was the second highest expected NPV of \$26,153 ha^{-1} and the lowest variability in NPV. Planting a cover crop thus decreased expected NPVs for both till and no-till planting. No-till planting with winter wheat had the highest expected NPV of all the cover crop treatments of \$25,521 ha^{-1}. Planting a cover crop did not appear to have a clear effect on the variation in expected NPVs. For no-till, planting cover crops resulted in higher variation of NPV than no cover crops. Variation in expected NPV with till was lower with hairy vetch than no cover crop, but variation in expected NPV with till was higher with winter wheat than no cover crop.

Risk Analysis of Net Present Value

Figure 1 presents the CDFs of NPVs for each cover crop and tillage combination. The CDFs show that first- and second-degree stochastic dominance does not exist for a cover crop and tillage combination because the CDFs intersect. SERF was used to determine the optimal combination of cover crop and tillage practices at different levels of absolute risk aversion. Figure 2 shows the utility-weighted risk premiums for each scenario. A risk-neutral (ARAC = 0) producer (or profit-maximizer) would prefer till with no cover crops; however, a slightly-risk averse to highly-risk averse (AREC = 0.03) producer would prefer no-till planting with no cover crops. A slightly-risk averse producer would require a payment of \$198 ha^{-1} to switch from no-till planting with no cover crop to till planting with a cover crop. No-till planting was found to reduce risk for cotton producers, which is different from what Larson et al. (2001) observed. This differences suggests that the risk benefits associated with no-till might take many years of continuous use before they are realized by producers, which is consistent with Soule et al.'s (2000) findings.

<<<<INSERT FIGURE 1 APPROXIMATELY HERE>>>>

<<<<INSERT FIGURE 2 APPROXIMATELY HERE>>>>

Planting cover crops generated mixed results in the risk analysis. A profit-maximizing producer would select no-till planting with winter wheat over all other cover crop treatments. However, a risk-averse producer would prefer till with hairy vetch over all other cover crop treatments. With no-till, a producer would always prefer planting winter wheat over hairy vetch. Conversely, a producer using till would prefer hairy vetch over winter wheat. These results suggest cover crops did not reduce producer risk relative to no cover crops.

Conclusion

We determined the profitability and risk of alternative winter cover crop and tillage systems in cotton production. Simulation models were developed to generate distributions of NPV for investing into the long-term use of cover crop and tillage systems. Data were collected from a 29-year cotton N, tillage, and cover crop experiment in West Tennessee. The cover crops treatments were no cover crop, winter wheat, and hairy vetch while the tillage systems were no-till and till. Therefore, distributions were generated for six different cover crop and tillage combinations.

A common limitation of the economic literature on cover crops and no-till production is the use of short-term datasets to determine the profitability and risk from using these practices. This has resulted in inconsistent economic findings of planting cover crops and no-till. Therefore, analyzing the profitability and risk associated with cover crops and no-till production using a long-term dataset would make a unique contribution to the literature. Results will provide robust insight into the profitability and risk of using cover crops and no-till. Furthermore, we measure profitability using a unique approach from previous studies. Typically, producer's profits from using cover crops and no-till is measured on an annual bases, but we analyze the producer's decision to use cover crops and no-till using present value of net returns over an extended period of time.

Profit-maximizing N rate and yields varied across the cover crop and tillage combinations. The highest profit-maximizing N rate was found for till cotton with no cover crop and lowest for no-till cotton with hairy vetch. This differed from what Larson et al. (2001) observed, indicating continuous use of cover crop and no-till over time can change profit-maximizing N rates for cotton. Profit-maximizing yields were on average highest for till cotton with no cover crop and the lowest profit-maximizing yield was for no-till cotton with no cover crop. A profit-maximizing producer would prefer a till planting with no cover crop system. However, a slightly-risk averse to highly-risk averse producer would prefer no-till planting with no cover crops. This differences suggests that the risk benefits associated with no-till might take many years of continuous use before they are relieved by producers.

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

N Rate	No Cover	Winter Wheat	Hairy Vetch
		Conventional Till	
0	827 (276)	745 (219)	969 (299)
34	943 (295)	931 (266)	1,084 (361)
67	1,031 (345)	1,034 (351)	1,058 (369)
101	1,106(351)	998 (331)	1,010 (365)
		No- Till	
0	683 (267)	695 (222)	974 (321)
30	912 (274)	942 (248)	1,074 (355)
60	1,053 (344)	1,055 (328)	1,042 (370)
90	992 (363)	1,038 (319)	947 (403)

Standard Deviation in parentheses

Table 2. Summary Statistics for Prices used in the Net Present Value Simulation Model

Price	Average	Standard Deviation	Minimum	Maximum
Cotton Lint Price[a] ($ kg^{-1})	$1.77	0.535	$0.85	$2.33
Nitrogen Price[a] ($ kg^{-1})	$1.08	0.267	$0.77	$1.77
Hairy Vetch[b] ($ kg^{-1})	$4.59	0.278	$3.92	$4.64
Winter Wheat[b] ($ kg^{-1})	$0.84	0.163	$0.48	$1.45

All prices were adjusted to 2012 dollars using the Implicit Gross Domestic Product Price Deflator (United States Bureau of Economic Analysis, 2016).

[a] Cotton lint and ammonium nitrate prices were collected from 1984-2012 (USDA National Agricultural Statistical Service (NASS), 2016).

[b] Cover crop seed prices were collected from 2006-2012 through personal communication with the Tennessee Farmer Cooperative.

Table 3. Parameter Estimates of the Cotton Yield Response Function to Nitrogen and Time by Winter Cover Crop and Tillage System

	Conventional Till			No-Till		
Parameter[a]	No Cover	Winter Wheat	Hairy Vetch	No Cover	Winter Wheat	Hairy Vetch
Intercept (β_0)	1289.290***	1342.243***	1438.477***	1113.753***	969.020***	1307.988***
t (β_3)	-137.753***	-146.580***	-158.990***	-149.962***	-99.234***	-153.097***
t^2 (β_4)	8.669***	8.669***	10.801***	10.437***	6.919***	11.665***
t^3 (β_5)	-0.151***	-0.145***	-0.189**	-0.195***	-0.127***	-0.222***
N (β_1)	3.177***	5.671***	2.484***	7.799***	8.673***	1.935
N^2 (β_2)	-0.039***	-0.067***	-0.042***	-0.074***	-0.076***	-0.046***
N x t (β_6)	0.234***	0.242***	0.119***	0.204***	0.181***	0.129***
R-squared	0.294	0.361	0.323	0.412	0.395	0.331

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

Table 4. Profit-Maximizing Nitrogen Application, Lint Yield, and Net Present Value by Winter Cover Crop and Tillage System

	Conventional Till			No-Till		
Item	No Cover	Winter Wheat	Hairy Vetch	No Cover	Winter Wheat	Hairy Vetch
Profit-Maximizing N Rate	95.71	76.48	49.55	77.53	79.11	37.70
(kg ha^{-1})	(23.72)	(6.00)	(7.99)	(6.15)	(5.37)	(8.50)
Profit-Maximizing Yield	1,155	1,133	1,132	1,082	1,142	1,089
(kg ha^{-1})	(39.58)	(17.89)	(19.76)	(16.10)	(14.03)	(18.99)
Profit Maximizing Net	$26,815	$25,024	$25,103	$26,153	$25,521	$24,620
Present Value ($ ha^{-1})	(7,583)	(7,642)	(7,554)	(7,159)	(7,579)	(7,143)

Standard Deviation in parentheses

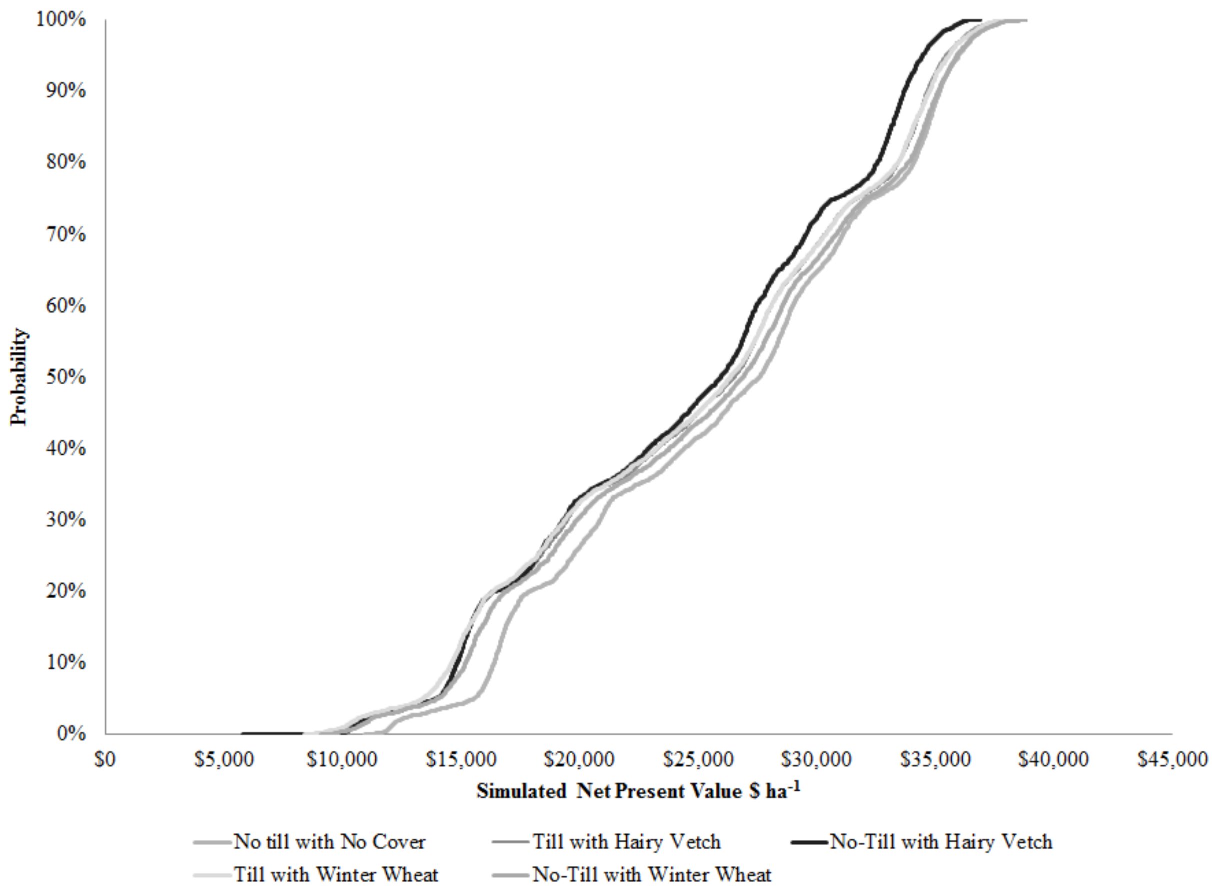

Figure 1. Cumulative Distribution Function of Net Present Values (\$ ha^{-1}) for each Cover Crop and Tillage Combination

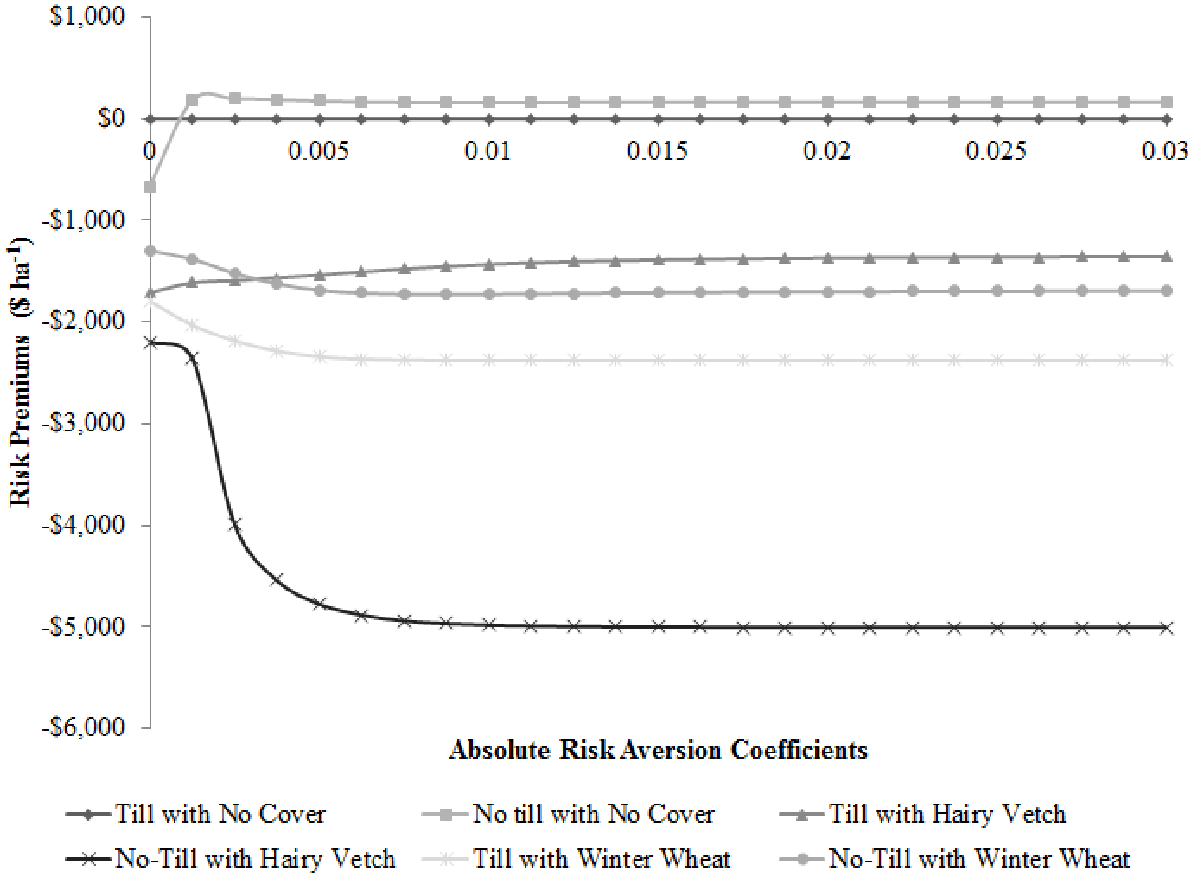

Figure 2. Utility Weighted Risk Premiums for each Cover Crop and Tillage Combination