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Estimating risk premiums for adopting no-till and cover crops management practices in soybean production system using stochastic efficiency approach

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ABSTRACT

Several alternative conservation practices that address farmers' concerns over natural resource stewardship are currently available. Such conservation practices as the planting of cover crops and conservation tillage are some of the most widely promoted practices throughout the U.S. today. Based on three-years (2016–2018) of field data and historical market price, crop yield, crop price, and fuel and fertilizer price are simulated to create net return distributions. To evaluate the profitability of conservation alternatives and the risk efficiency of these alternatives, the stochastic efficiency with respect to a function (SERF) method is used for analyzing the no-till and cover crop management systems in Louisiana soybean production. SERF estimates certainty equivalents (CE) in order to rank a set of risk-efficient alternatives over a range of risk aversion preferences. Results indicate that CE values are higher for conventional tillage practices than for no-till and risk premiums are positive across all risk-aversion values; however, for risk-averse farmers, premiums are almost zero if their current system is either a no-till or conventional tillage system where the farmer has already implemented a cover crop.

1. Introduction

Since the 1985 Farm Bill, the adoption of proven soil and water conservation practices has been mostly on an upward trend. The 1985 Farm Bill heightened awareness for the need of both soil and water conservation and provided conservation incentives to enhance the adoption of those practices. Agricultural researchers in Louisiana and across the southern United States, in collaboration with scientists at the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), extension professionals, private crop consultants, and farmers evaluated comprehensive conservation systems and promoted their adoption (Hellerstein et al., 2019). The NRCS widely supports winter cover crops and conservation tillage through programs such as the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP), whose aim is to promote the mitigation of soil erosion and improve nutrient recycling in the soil profile. Benefits from adopting conservation practices include erosion prevention, improved soil structure and organic matter, enhanced weed suppression, conservation of soil moisture, protection of water quality, among others (Vyn et al., 1999; Wyland et al., 1996). Approximately 70% of soybean, 40% of cotton, 65% of corn, and 67% of wheat acreage in the United States have some form of conservation tillage (Hellerstein et al., 2019). Duzy (2017) pointed out that cover cropping in the Southeast has become more common because of benefits in weed suppression. The author also mentions another possible reason for adoption is the relative ease farmers have in establishing and terminating a winter cover crop in the Southeast, which enjoys a longer growing season than do most other regions in the country.

Those conservation incentives mentioned previously are quite sizable. EQIP obligations amounted to $56 million in the fiscal year 2015 for cover crops. Despite the existence of programs supporting nationwide conservation initiatives, implementation of these practices is still relatively low across the United States (Adusumilli and Connor, 2018; Dunn et al., 2016; Ma et al., 2012; Wade et al., 2015). This low rate of adoption could be ascribed to the challenges farmers face in establishing and maintaining a cover crop, including the labor and time requirements for both cover crop and conservation tillage implementation. Along with those challenges previously mentioned, the profitability associated with planting cover crops and using no-till may also be useful in explaining adoption patterns (Wade et al., 2015). Changes in yield, mostly downward, in the initial years of a no-till system and the increase in production costs in cover crop management can affect overall profits. Therefore, the economic efficiency of incorporating these practices into a traditional farm production system is

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highly contextual and should be evaluated periodically to identify the programs' overall impact on farm profitability.

In addition to the impact on farm profitability, the perceived risk of these practices, mostly negative, had a significant influence on the decision to adopt conservation practices (Larson et al., 2001; Pendell et al., 2006; Archer and Reicosky, 2009). More specifically, the risk associated with the trade-off between upfront investment and the delay in program benefits often plays a critical role in adoption decisions (Fathelrahman et al., 2011). As individuals' risk preferences differ, comparing net farm income distributions from a set of management alternatives, which were made under general assumptions of the utility function can assist with the development of incentives that are most likely to motivate conservation practice(s) adoption among farmers (Adusumilli et al., 2016; Boyer et al., 2015). The objective of this study is to evaluate both the profitability of conservation alternatives and the risk efficiency of these alternatives in Louisiana soybean production.

2. Literature review

Under conditions of risk, mean-variance and stochastic dominance approaches were used in the past to analyze decisions with respect to conservation practice adoption, which then allow for the selection of preferred practices from a set of outcome distributions (Fieberg and Ellner, 2001; Mercer, 2004; Hanks and Martin, 2007; Davey and Furtan, 2008; Björk et al., 2014; Buckley et al., 2015; Boyer et al., 2018). The stochastic method allows for the modeling of many risk attitudes and estimation of risk premiums, the amount that decision-makers are willing to pay to maintain or modify their existing practice(s). Larson et al. (2001) used first and second-degree stochastic dominance methods for evaluating the net returns associated with cover crop adoption along with various nitrogen rates in no-till corn systems in Tennessee. The authors found that cotton grown after hairy vetch is the risk-efficient alternative for risk-averse farmers who have already adopted no-till. Similarly, DeVuyst and Halvorson (2004) used the same method to rank 18 continuous cropping and crop-fallow treatments varying by tillage and nutrient management method in the Northern Great Plains. Stochastic dominance analyses showed that both spring wheat-fallow systems and intensive cropping systems with conventional tillage treatments were economically inefficient when compared with intensive cropping systems with minimal or no-till. Pendell et al. (2006) used the stochastic dominance method to examine the net returns of continuous corn production under conventional and no-till systems and to quantify the value of carbon sequestration credits. The results indicated that extremely risk-averse farmers prefer a system that sequesters less carbon because there is less potential loss in return. Giesler et al. (1993) used stochastic dominance with respect to a function (SDRF) approach to evaluate the relative economic feasibility of using alternative cover crop systems in a cotton production system to conventional cotton production (fallow). Results show that hairy vetch and vetch along with 40 pounds of nitrogen are viable alternatives to conventional practices. Harmon et al. (2018) utilized a long-term experiment dataset to determine the influence of four winter cover crops and two tillage systems on the optimal nitrogen rates, cotton yields, and net returns for risk-neutral to risk-averse cotton producers. The authors employed a flexible moment model where skewness or downside risk (the third moment) was used to estimate the impact risk has on a farmer's decision to plant cover crops and implement alternate systems of tillage. They found that a risk-neutral producer would select a conventional tillage system and no cover crop but discovered that as risk aversion increases, a no-till system with no cover crop was optimal.

An alternative to those previously discussed methods is stochastic efficiency with respect to a function (SERF). Unlike conventional stochastic dominance approaches, SERF uses the concept of certainty equivalents (CEs) as a selected measure of risk aversion in order to rank a set of utility efficient alternatives (Hardaker et al., 2004; Schumann et al., 2004). Keeney and Raiffa (1993) suggested that the CE is the net return with the same utility as the expected utility of a risky alternative, which is calculated using the inverse of a utility function. SERF can potentially identify a small efficient set as compared to SDRF with the added benefit of being more transparent and easier to implement. The CE is the amount of money an individual would require to be indifferent between the payoff from the current production practice and from a risky alternative. The CE is usually less than the expected money value (EMV) and greater than or equal to the minimum money value for a risk-averse decision-maker.

Watkins et al. (2008) used SERF to evaluate the profitability and risk efficiency of no-till rice production in Arkansas. Results showed that risk-neutral and risk-averse tenants would benefit from a no-till practice in rice, but risk-neutral landlords would be indifferent between no-till or conventional-till. Archer and Reicosky (2009) used SERF to evaluate residue management and tillage alternatives in corn and soybean production. They concluded that strip-till and no-till are economically practicable systems compared to conventional tillage. Williams et al. (2009) used SERF to evaluate both wheat and grain sorghum production systems under three different tillage practices in lieu of enrollment in the conservation reserve program (CRP). Their results showed that CRP enrollment is the preferred strategy for risk-averse farmers, whereas risk-neutral farmers would prefer a crop production system irrespective of tillage method. Also, Boyer et al. (2018) used SERF to evaluate the profitability and risk of several combinations of cover crop and till practices for cotton production in Tennessee. Results indicated that risk-neutral producers would prefer till planting and not planting a cover crop. Risk-averse producers prefer no-till planting with no cover crop. Thus, SERF can be used to evaluate various conservation alternatives when considerations of risk are involved. This analysis uses three-year field data from northwest Louisiana. The primary goal of this study is to utilize SERF for stochastically evaluating the economic profitability of a soybean production system when combined with cover crops and alternative tillage practices over a range of risk preferences.

3. Material and methods

3.1. Data

Soybean production and price data were compiled from several sources and used to conduct this partial-budget analysis. Soybean yield distributions under cover crops in conventional tillage with and without cover crops and no-till with and without cover crops in a non-irrigated system were simulated using data from 2016 to 2018 (Table 1). The experimental area was under a soybean and corn rotation with conventional tillage for many years until 2013 at the Red River Research Station located in Bossier City, Louisiana. Beginning in the spring of 2014, the experimental area was imposed with no-tillage and conventional tillage treatments with soybean as the principal crop. Winter cover crop treatments were initiated beginning in the winter of 2014 using a randomized complete block with a split-plot design. Cover crops were grown for 125, 136, and 136 days in the winters of years 2015,

Table 1
Average soybean yields (kg/ha) by winter cover crop and tillage system from 2015 to 2017.

Production system	Mean	St. Dev.	Minimum	Maximum
Dryland Soybeans in a No-till system (kg/ha)				
No-till; no cover crop	2909	339	2531	3185
No-till; hairy vetch	3213	307	2984	3561
No-till; wheat	2925	544	2502	3539
Dryland Soybeans in a conventional tillage system (kg/ha)				
Conventional tillage; no cover crop	3242	268	3065	3551
Conventional tillage; hairy vetch	3418	484	2965	3928
Conventional tillage; wheat	3079	409	2721	3524

2016, and 2017, respectively. No fertilizer was applied either for cover crop or main crop (soybeans) during the experimental period. Weather during the winter 2016 cover crop season was warmer than that of the winters for both 2015 and 2017 cover crop seasons, while precipitation in the winter of 2016 was lower compared to other experimental years. Overall, average temperatures during the winters of 2015, 2016, and 2017 cover crop seasons were 9.6, 12.1, and 8.9 degree Celsius (°C), respectively. During 2016, 2017, and 2018 soybean growing seasons, the average temperature was 24.2, 23.2, and 24.9 °C, respectively. Total cover crop season precipitation for years 2015, 2016, and 2017 was 853, 299, and 498 mm, respectively, while total precipitation during 2016, 2017, and 2018 soybean growing seasons was 624, 573, and 231 mm, respectively. Mean annual temperatures during the experimental years were similar to historical temperatures while precipitation was significantly higher in 2016 and 2018 (+22 and + 29%, respectively) but lower in 2017 (−16%). Monthly rainfall distribution during the experimental years; however, was highly sporadic compared to the 30-year average. This is especially true for June and July in 2018 when soybeans were in their moisture-sensitive growth stages, there was only 67.3 mm of total rainfall as compared with the region's historical average of 217.7 mm. Nearly half of the total rainfall for 2018 occurred in the months of October, November, and December.

Historical yields were detrended using linear regression and residuals from the trend were used to estimate the parameters for the multivariate empirical (MVE) yield distributions. The mean yields over the 3-year period were used as expected yields for the MVE distributions. Crop yields and prices, along with prices for both fuel and fertilizer were simulated using the Microsoft Excel© add-in, SIMETAR (Richardson et al., 2008). Net returns for a soybean production system were simulated by iteration, cover crop treatment, tillage treatment, and irrigation treatment. The MVE distributions were used to simulate 1000 iterations of yields and prices. The MVE distribution provides the option to use limited observations of historical data (three-year of actual field data is used) and can appropriately correlate random variables based on their historical correlation (Richardson et al., 2008). Parameters for the MVE distribution include the means, deviations from the mean or trend (expressed as a fraction of each variable), and the correlation among variables.

Direct and fixed expenses and input data for soybean production for the analysis were based on Louisiana annual crop budget reports (Deliberto et al., 2016; Deliberto et al., 2017). Direct expenses included costs for seed, pesticides, labor, fuel used for both farm equipment and irrigation purposes, repair and maintenance of farm equipment, depreciation and interest. Conservation practice implementation might save on some input costs but requires other operations such as additional chemical applications for weed-control and termination. Net returns are then estimated per hectare for the soybean production system based on the 1000 simulated iterations.

3.2. SERF method

The SERF analysis uses utility efficient alternatives for ranges of risk attitudes. This method considers the full range of decision-maker preferences and is considered a more discriminatory and efficient technique (Hardaker et al., 2004). Schumann et al. (2004) noted that choosing utility functions with the assumption of concavity in the range of risk aversion and weighting them to create a composite ranking can be useful to analyze decision maker's choices under quasi-risk aversion conditions. In this study, a negative exponential utility function is used in conformity with the hypothesis that farmers prefer less risk to more, given the same expected return. The negative exponential function indicates that farmers have a constant absolute risk aversion and view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth (Babcock et al., 1993; Pendell et al., 2007). The negative exponential function can be used as a reasonable approximation of risk averting behavior (Schumann et al., 2004; Williams et al., 2009). Hardaker et al. (2004) outlined the methodology for analyzing risky alternatives. CE values over a range of absolute risk aversion coefficients (ARACs) are calculated. While the coefficient of absolute risk aversion can be applied to consequences measured in terms of wealth or income (Anderson and Hardaker, 2003). ARAC represents a decision-makers' degree of risk aversion. If ARAC > 0, ARAC = 0, or ARAC < 0, the decision-makers are classified as risk-averse, risk-neutral, or risk preferring, respectively. ARAC values were calculated using the following formula proposed by Hardaker et al. (2004):

$$ARAC_w = \frac{r_r(w)}{w} \tag{1}$$

where $r_r(w)$ represents the relative risk aversion coefficient with respect to wealth (w) and r_r (w) was set to 0 (for risk-neutral farmer) to approximately 4 (very risk-averse farmer) as proposed by Anderson and Dillon (1992). In this study, wealth (w) was calculated based on the respective net return means from cover crops in no-till, cover crops in conventional tillage, cover crops in conventional tillage in irrigated soybeans, cover crops in conventional tillage in non-irrigated soybeans. The ARAC values ranging from 0 to 0.04 corresponds to relative risk aversion coefficient range of 0 to 4. Thus the ARAC values in the range of 0 to 0.04 were used in the SERF analysis to calculate CE values for soybean under each of the conservation alternatives.

CE graphs were constructed to display ordinal rankings of conservation practices across the specified range of ARAC values. Graphical presentation of SERF results facilitates the presentation of ordinal rankings for decision-makers with different risk attitudes. CE graphs also provide a cardinal measure of decision-makers' preferences among risky alternatives at each risk aversion level by interpreting differences between CE values as risk premiums (Hardaker et al., 2004). Risk premiums for conservation practices are calculated by subtracting the CE values from the corresponding status-quo practice at given ARAC values.

4. Results

Summary statistics of simulated net returns to soybeans are presented by cover crops and tillage practice in Table 2. The mean net returns per hectare for the no-till system with control, with hairy vetch, and with wheat as cover crops were $146, $259, and $170, respectively. While mean net returns per hectare for conventional tillage with control, with hairy vetch, and with wheat as cover crops were $323, $339, and $232, respectively. The average returns to soybeans were higher under the presence of a cover crop in both no-till and conventional tillage systems. Overall, the returns are higher under the conventional tillage system. The standard deviations were relatively higher for the conventional tillage system indicating much more variability in returns.

CE and risk premiums are presented for various ARAC values in Table 3. CE values are higher for conventional tillage practices than for no-till at all levels of ARACs. Positive CE values indicate farmers would

Table 2
Summary statistics of simulated net returns by cover crops and tillage practice.

Production System	Mean	St. Dev.	Minimum	Maximum
Dryland Soybeans in a No-till system ($/ha)				
No-till; no cover crop	146	154	−334	621
No-till; hairy vetch	259	196	−345	851
No-till; wheat	170	275	−841	1055
Dryland Soybeans in a conventional tillage system ($/ha)				
Conventional tillage; no cover crop	323	97	30	600
Conventional tillage; hairy vetch	339	235	−601	1070
Conventional tillage; wheat	232	221	−447	951

Table 3
Certainty equivalents and risk premiums for various Absolute Risk Aversion Coefficients.

Absolute Risk Aversion Coefficient (ARAC)					
	0.00	0.01	0.02	0.03	0.04
Tillage practice; cover crop	Certainty Equivalents ($/ha)				
No-till; no cover crop	146	98	52	11	−25
No-till; hairy vetch	259	177	99	32	−23
No-till; wheat	170	−1	−163	−292	−382
Conventional tillage; no cover crop	323	303	284	265	247
Conventional tillage; hairy vetch	339	230	126	39	−28
Conventional tillage; wheat	232	136	37	−59	−139
No-till Hairy Vetch risk premiums ($/ha)					
No-till; no cover crop	−113	−79	−47	−20	−2
No-till; hairy vetch	0	0	0	0	0
No-till; wheat	−89	−177	−262	−324	−359
Conventional tillage; no cover crop	64	126	184	233	270
Conventional tillage; hairy vetch	80	53	27	7	−5
Conventional tillage; wheat	−27	−41	−62	−91	−116

need premiums to shift from a conventional tillage practice to a no-till practice. The result seems reasonable as no-till practices are shown to have lower yields in their initial years of adoption. In addition, when farmers convert to a no-till production system, they face the possibility of losing their capital investment in tillage equipment.

4.1. *Risk premiums for "no-till Hairy Vetch" system*

For discussion purposes, premiums to move to a no-till hairy vetch system from other systems are presented (Table 3). The risk premium, which is the amount required to induce a change in practice is estimated. A risk-neutral farmer (ARAC = 0.0; a profit maximizer) is willing to pay $64 ($323–$259-the difference in CE values under that ARAC value) to stay in a conventional tillage with no cover crop production system than adopt a no-till with hairy vetch production system or willing to accept (would need) the same amount to move to a no-till hairy vetch production system. The amounts estimated here show that if the net returns are at least $64, a farmer is willing to make changes to their tillage and ground cover practices.

For the risk-neutral farmer (ARAC = 0.0) currently adopting a no-till with no cover crop production system, that farmer would need $113 for continuing in the current production system or would be willing to pay $113 ($146–$259- the difference in CE values under that ARAC value) to move to a no-till hairy vetch system, as net income is higher under the latter system. This situation indicates that it is likely easier to convince farmers who currently implement a no-till production system to add a cover crop and the incentive needed to make that change is -$113 or $0. This could be a result of some variable cost savings (i.e., reduced fertilizer use) and/or productivity improvement associated with a cover crop on the ground. Risk premiums estimated in this manner should serve as a guide to the NRCS, the agency which offers incentives to implement conservation. These incentives are usually based on costs incurred to implement those practices; however, when dealing with farmers with different risk tolerance levels, it is important to account for their risk behavior and identify the incentive level that motivates the adoption of conservation practices. In addition, these estimates can serve the purpose of guiding decision making with regards to identifying crop insurance subsidy premiums for conservation adoption. The risk premiums estimated at a given ARAC level for each conservation practice could be the subsidy amount that can be applied toward crop insurance premiums for those acres with conservation, thus rewarding conservation stewardship behavior.

Similar conclusions were reached by Canales et al. (2015), where they estimated that farmers would be willing to pay around $22 per hectare to continue in a no-till production system as some of those

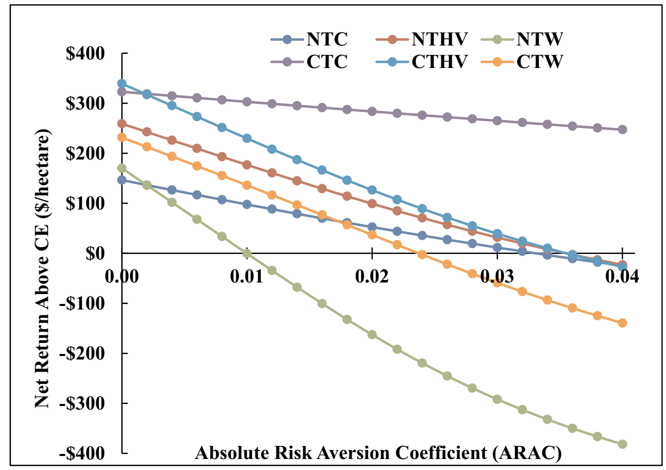

Fig. 1. SERF results for soybean net returns (CE) over absolute risk aversion range of 0.00 to 0.04 assuming negative exponential utility function.

investments can be irreversible in the short-run. Watkins et al. (2008) and Williams et al. (2009) found no-till production systems to be ranked higher than conventional tillage systems across the entire range of risk aversion coefficients in a rice-soybean rotation and a 3- year wheat-sorghum-fallow rotation, respectively. This result is consistent with our estimates. Fig. 1 shows the CE values for all practices across all ranges of risk aversion.

NTC: No-till with control; NTHV: No-till with hairy vetch; NTW: No-till with wheat; CTC: Conventional tillage with control; CTHV: Conventional tillage with hairy vetch; CTW: Conventional tillage with wheat.

5. Conclusions

The analysis evaluated the profitability and risk efficiency of no-till and cover crops in a continuous soybean production system in Louisiana using simulation models and stochastic efficiency with respect to a function (SERF). Three years of field data on crop yields from continuous soybean production under different tillage and cover crop treatments were combined with price and input cost data to estimate net returns. Net return distributions were constructed for each production system. The preference for an alternative management system depends upon the producer's attitude toward risk. We found that for those producers practicing conventional tillage, risk premiums are smaller for risk-neutral producers, whereas, they are high for risk-averse producers.

Risk premiums are highly dependent on the net returns of the production system. Information about risk premiums can have important policy implications. As national conservation initiatives are designed and implemented to increase adoption rates of conservation practices on working lands, understanding the incentives needed to initiate those changes can often be the deciding factor between the success and failure of those programs, and the overall attendant design, which is environmental improvement.

Creating a national/regional initiative with the aim of promoting conservation practices would need some level of funding support to cover any variability in yields and gross margins arising from a change in production methods. The NRCS annually updates its cost-share payment amounts for several conservation practices. The risk premiums estimated in this analysis can provide an evaluation of conservation behavior as a result of payment changes. These estimates can also be useful in providing an ex-ante evaluation of minimum payment amounts necessary to achieve adoption goals, consequently allowing evaluation of a program's success and/or failure.

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Declaration of competing interest

None.

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