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A GSD Estimation of the Relative Worth of Cover Crops in Cotton Production Systems

G. Grant Giesler, Kenneth W. Paxton, and E. P. Millhollon

Cover crops can help reduce the negative environmental impacts of cotton production. Using time series yield data, this study utilizes generalized stochastic dominance to evaluate the relative worth, via risk premiums, of three cover crop and two conventional production systems based on expected net returns of each system and decision maker risk attitude. Results indicate, within the limitations of the study, two cover crop regimes possess a high degree of dominance over conventional systems. Determination of the dominant regime depends upon the risk attitude of a specific decision maker. This research suggests cover crop production systems may be feasible alternatives to conventional practices.

Key words: cotton, cover crops, generalized stochastic dominance, risk premiums.

Introduction

Cotton acreage in Louisiana and the southeastern United States has expanded during a period when there has been growing public concern regarding the environmental impacts associated with the production of cotton and many other row crops. From the producer's perspective, there are also growing uncertainties associated with the price and availability of petroleum-based nitrogen fertilizers and the corresponding firm level effects on profitability. Although current nitrogen fertilizer costs are a relatively small component of total production costs for a representative Louisiana cotton producer, this situation could be altered significantly depending on several factors, most notably world oil and natural gas prices. This factor, coupled with the detrimental environmental impacts associated with conventional production practices (topsoil erosion and nitrate runoff) and consequent potential for legislation being incorporated into future Food Security Acts that would limit production methods, could drastically affect commercial cotton production practices and net returns to cotton production. This study incorporates risk attitudes to evaluate the relative economic feasibility of using cover crops (grasses and legumes) to supply all or part of the nitrogen required by cotton.

Cotton makes a significant contribution to the economies of many major cotton producing states, including Louisiana (Louisiana State University Agricultural Center). Any changes mandated by legislation, which would alter yields and net returns, could have extremely important economic consequences for cotton producing regions within the state and significant implications for the entire state.

An underlying premise of this analysis is the generally accepted reasoning that the use of cover crops to provide winter ground cover significantly reduces soil erosion and, where those cover crops are legumes, also reduces nitrate runoff by decreasing the use of com-

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Grant Giesler and Kenneth Paxton are, respectively, research associate and professor, Department of Agricultural Economics and Agribusiness, Louisiana State University. E. P. Millhollon is an assistant professor with the Red River Research Station, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center.

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mercial nitrogen fertilizers. Given this, the use of cover crops implies smaller environmental impacts stemming from cotton production and is in line with the precepts of low input sustainable agriculture (LISA).

Stochastic Dominance Analysis

Stochastic dominance (SD) techniques have been used to order numerous kinds of farm management decisions that must be made in an environment of risk and uncertainty. Examples include (among many others) Klemme; Lee, Ellis, and Lacewell; Kramer and Pope; and Williams. There are three commonly used forms of stochastic dominance: first degree (FSD), second degree (SSD), and stochastic dominance with respect to a function (SDWRF or GSD). A major advantage of stochastic dominance is the implicit incorporation of more moments of the comparison distributions than other techniques such as mean-variance (E-V) analysis. Although under certain conditions, mean-variance may not require normality in the probability distribution functions (PDFs), it is always the case that stochastic dominance criteria never require normality. Therefore, most data sets are more readily amenable to evaluation by stochastic dominance.

While FSD and SSD may be more useful than E-V analysis, they are not as efficient as GSD in selecting the preferred strategies from the outcome distributions. FSD is limited in narrowing the efficient set from the choice set because it makes only the weak assumption that more is preferred to less by the decision maker. SSD incorporates this assumption, plus the stronger assumption of risk aversion at all income levels. Due to this additional assumption, SSD can define a smaller efficient set than FSD, but it excludes the entire class of risk-preferring decision makers. GSD is a generalized technique that is often more useful because it does not impose global restrictions on the decision maker's utility function. Therefore, it can be used to model a wider spectrum of risk attitudes than either E-V analysis or SSD, via the Pratt risk aversion coefficient.[1]

Mathematically, the Pratt risk aversion coefficient is defined as $-U''(x)/U'(x)$, where U represents an individual's or a group of decision makers' utility function and x is income or wealth. By using the Pratt risk aversion coefficient to specify the lower and upper bounds ($r1$ and $r2$), a definite range on the admissible set of utility functions is established, thereby setting lower and upper limits on the range of risk attitudes that enter into the analysis.[2]

GSD allows the modeling of many different risk attitudes, by varying $r1$ and $r2$, without having to represent exactly any specific risk attitude. In addition, it also allows the calculation of risk premiums, or the amounts that decision makers would be willing to pay to maintain the use of the dominant distribution over a comparison distribution.

Data

This research used data originating from an ongoing cover crop study being conducted at the Red River Research Station in Bossier City, Louisiana, and which was instituted approximately 30 years ago (Millhollon and Melville). This study evaluates yield differences between different cover crop cotton production systems, even different legume cover crops, as well as evaluating the effects of cover crops used in conjunction with conventional nitrogen fertilizers. A total of eight treatments comprise the study: (*a*) wheat and 60 lbs. nitrogen (WH60N), (*b*) Austrian winter peas (AWP), (*c*) hairy vetch (HV), (*d*) check (CHECK) (no cover crop or nitrogen fertilizer), (*e*) common vetch (CV), (*f*) vetch and 40 lbs. nitrogen (VE40N), (*g*) 40 lbs. nitrogen (40N), and (*h*) 60 lbs. nitrogen (60N).

The actual data used in this analysis encompassed 22 years, 1968–89 inclusively. Truncation of the data (from 30 years) was necessary due to variation in experimental treatments during the early stages of the cover crop study. Each treatment in the cover crop study was replicated four times. For purposes of this analysis, yields from each replication were

Table 1. Lint Yield for Selected Production Systems, Red River Research Station, Bossier City, Louisiana, 1968-89

Year	Production System					
	HV	CHECK	40N	60N	WH60N	VE40N
	(lbs. per acre)					
1968	638	435	611	648	710	648
1969	468	287	445	446	374	421
1970	859	640	854	873	891	870
1971	825	579	763	731	782	720
1972	889	542	776	867	979	926
1973	550	280	488	523	515	544
1974	813	458	709	736	762	677
1975	592	224	459	534	483	566
1976	867	272	595	632	798	870
1977	835	512	776	854	790	811
1978	792	400	686	624	755	870
1979	830	326	833	830	822	953
1980	702	344	582	592	720	809
1981	744	256	648	624	707	766
1982	975	327	790	811	984	887
1983	743	191	552	558	657	766
1984	1,380	605	1,222	1,140	1,096	1,449
1985	924	429	720	889	1,033	927
1986	475	211	420	442	475	463
1987	828	174	507	584	734	822
1988	937	234	791	871	787	939
1989	977	274	613	842	834	738
Avg.	802	364	675	711	759	793

averaged over replications to negate any measuring error in the field. The actual treatments evaluated consisted of all of the above except for AWP and CV.[3]

Table 1 shows average (over four replications) lint yields for each production system for the 22 years of data used in this analysis. In order of descending mean yields, the systems are HV, VE40N, WH60N, 60N, 40N, and CHECK.

Procedure

The yield data provided by the Red River Research Station were expressed in pounds of seed cotton per acre. Seed cotton yields were converted to pounds of lint and cottonseed based on percentages published by the U.S. Department of Agriculture, Economic Research Service (USDA–ERS) for Louisiana in the 1988–89 season (Glade and Johnson).[4] Over the course of the cover crop study, new production technology (cotton varieties, defoliants, herbicides, and insecticides) was utilized as it became commercially available, thereby possibly contributing to an "across the board" upward trend in yields. Conversely, continuous cropping, even with cover crops, could cause significant downward yield trends due to changes in organic matter, soil erosion, and other agronomic considerations. However, neither linear nor curvilinear trend analysis revealed the existence of any broad-based trend. Therefore, the trends that were present were assumed to be solely the result of a specific treatment (cover crop) and no detrending procedures were used.[5]

After calculating the yields for each treatment in terms of both lint and cottonseed components, standard enterprise budgets, altered to reflect cultural practices specific to the Red River study, were constructed for each treatment. Unit input and output prices were held constant at 1990 levels to isolate the stochastic effects of yields on net returns. Consequently, input costs, with the exception of ginning costs, do not vary within treatments. However, they do vary between treatments, introducing an element of economic

Table 2. Mean, Standard Deviation, Maximum, Minimum, and Skewness Values for Each Cotton Production System

Distribution	Mean	SD	Maximum	Minimum	Skewness
	(net returns, $/acre)				
HV	194.54	146.83	625.15	−54.24	.67
CHECK	−101.11	106.07	105.02	−243.20	.53
40N	120.59	134.13	528.36	−69.04	1.06
60N	145.47	130.34	464.77	−55.23	.40
WH60N	164.12	136.07	415.49	−122.34	−.26
VE40N	177.60	158.12	666.45	−99.37	.90

as well as production risk.[6] Output prices used in enterprise budget generation were $.50/lb. market price for lint, $.23/lb. deficiency payment for lint, and $.05/lb. for cottonseed products. These prices, and all input prices used in enterprise budget generation, are representative of 1990 prices realized by producers within the cotton program.

The Mississippi State Budget Generator (MSBG) microcomputer program was used to generate the distribution of net returns (over variable costs, fixed equipment costs, and overhead) for each treatment, with each distribution including 22 observations. These distributions were then entered into a generalized stochastic dominance program (Goh et al.). It should be noted that this program limits consideration to constant absolute risk aversion functions. Table 2 shows the mean, standard deviation, maximum, minimum, and skewness values of net returns for each distribution in terms of dollars per acre.

Due to a lack of specific information about the true risk preferences of cotton producers in Louisiana, the lower bound ($r1$) was set at the negative of the calculated Pratt risk aversion coefficient[7] (−.150049) for the first interval.[8] A systematic iterative procedure then was employed to search for the highest value (at six decimal places) of $r2$ that could be entered, while still allowing all rotations to be ranked without question. Following the establishment of this value, the $r1$ value for the second interval was set at the $r2$ value of the first interval plus .000001, and the highest value of $r2$ (at six decimal places) where all rotations could be ranked was again searched for iteratively. This procedure continued until the $r2$ value of the last interval was equal to the calculated Pratt risk aversion coefficient (.150049).[9]

Because the objective was to define the largest interval possible while still ranking all strategies, thereby disallowing Type II (inability to order) errors, interval width varies significantly, as does the probability of Type I (inaccurate ranking) errors (Cochran, Robison and Lodwick). The narrower intervals have a correspondingly higher probability of Type I errors compared to the wider intervals.

The initial intervals were generated using per acre net returns; therefore, the corresponding r-values are much larger than the sets of intervals typically seen in the literature. In an effort to make these original intervals comparable to the semi-standardized sets of intervals usually reported in the literature, a scaling procedure (described by Raskin and Cochran) was utilized. The actual transformation was performed by multiplying the per acre net returns by 415, which, based on a recent survey, is the average cotton acreage of a representative farm in the Red River area of Louisiana (Vandeveer, Boucher, and Huffman), and dividing the per acre interval bounds by 415.[10] Although a representative farm in this region has other income-producing enterprises besides cotton, income from the cotton enterprise generates approximately 70% of the projected operating receipts for these crop farms (Vandeveer, Boucher, and Huffman), and should therefore dominate decision making by the producer, even in a diversified management strategy.

After transforming the data, the interval bounds corresponding to whole farm income were carried out to eight decimal places, rather than six places as in the per acre intervals. This was necessary due to the small number of intervals that remained (at six decimal

Table 3. Risk Intervals and Rankings from Risk-Preferring to Risk-Averse

Interval	*r*1	*r*2	Rankings*
1	−.00036156	−.00002845	V,H,4,6,W,C
2	−.00002844	−.00002829	V,H,4,6,W,C
3	−.00002828	−.00002810	V,H,4,W,6,C
4	−.00002809	−.00002047	V,H,4,W,6,C
5	−.00002046	−.00002046	V,H,4,W,6,C
6	−.00002045	−.00001728	V,H,W,4,6,C
7	−.00001727	−.00001189	V,H,W,6,4,C
8	−.00001188	.00001865	H,V,W,6,4,C
9	.00001866	.00001930	H,V,W,6,4,C
10	.00001931	.00001931	H,V,W,6,4,C
11	.00001932	.00002081	H,V,6,W,4,C
12	.00002082	.00002700	H,V,6,W,4,C
13	.00002701	.00003366	H,6,V,W,4,C
14	.00003367	.00003367	H,6,V,W,4,C
15	.00003368	.00004618	H,6,V,4,W,C
16	.00004619	.00036156	H,6,4,V,W,C

* Where H = HV, 6 = 60N, 4 = 40N, V = VE40N, W = WH60N, and C = CHECK.

places) after being divided by 415, and the consequent presence of Type II errors. This result was accomplished by using the iterative procedure described previously, with the bounds divided by 415 providing starting points.[11] Intervals without Type II errors were checked to ensure that their bounds were still as wide as possible in order to minimize the probability of Type I errors. Neither the rankings nor the risk premiums (in equivalent units) changed as a result of the transformation.[12] The only difference was a slight reduction in the number of intervals, from 19 to 16.[13]

Another important aspect of GSD is the calculation of risk premiums associated with each interval. In the GSD program, both an upper and lower bound on the risk premium is calculated. "The upper bound corresponds to the minimum shift in the dominant distribution [or CDF] that results in the dominant distribution being dominated by the comparison distribution" (Cochran and Raskin, p. 6). The lower bound represents the minimum shift in the dominant distribution where both the dominant and comparison distributions are in the efficient set (Cochran and Raskin). Alternatively, the upper bound may be thought of as the largest amount that at least one decision maker in that interval would pay to use the dominant strategy as opposed to a competing (inferior) strategy, while all would be willing to pay an amount equal to the lower bound. Mathematically, following Cochran and Raskin, the following calculations are performed:

$$\text{Min } \pi \ni EU(F - \pi) - EU(G) < 0 \ \forall U \in u \tag{1}$$

and

$$\text{Min } \pi \ni EU(F - \pi) - EU(G) \leq 0 \text{ for at least one } U \in u, \tag{2}$$

where π = risk premium, EU = expected utility, F = dominant distribution, G = comparison distribution, u = admissible set of utility functions, U = individual decision maker's utility function, $\forall$ = for all, $\in$ = is an element of, and $\ni$ = such that. Equations (1) and (2) represent the upper and lower bounds, respectively.

Results

The intervals for whole farm income are given in table 3. The rankings of the treatments change significantly based on the risk attitudes of decision makers. One of the cover crop

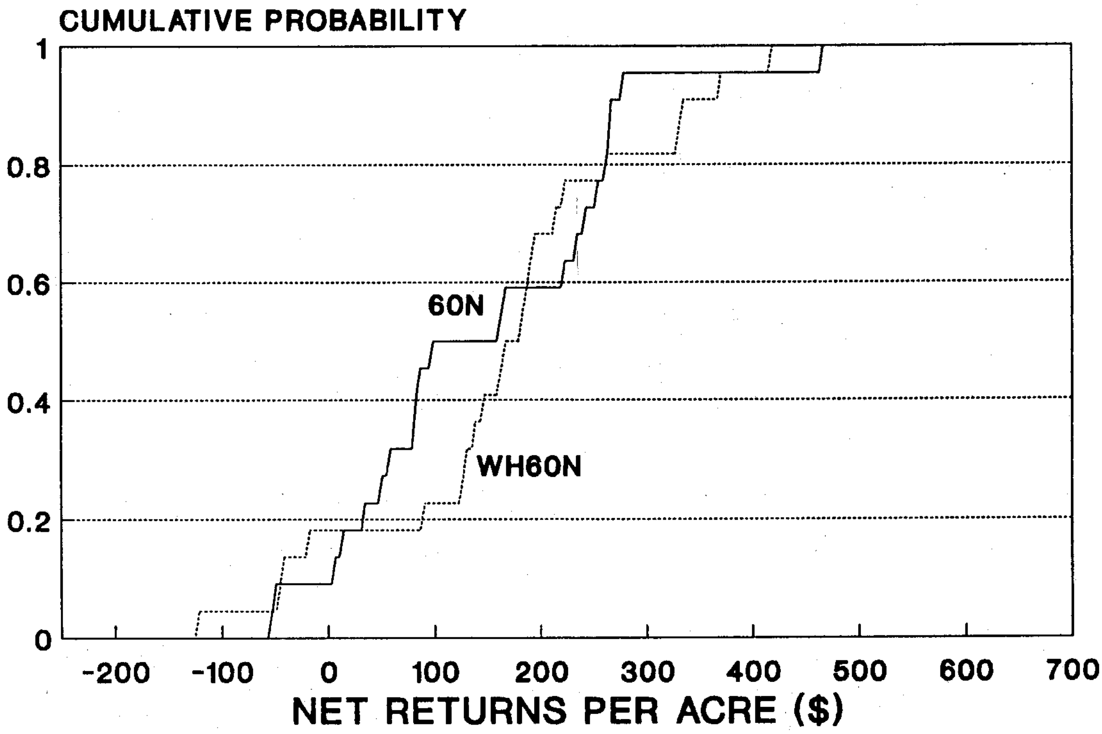

Figure 1. Cumulative distribution functions for WH60N and 60N

production strategies, either HV or VE40N, is ranked highest across all intervals. Across intervals 6–10, inclusively, cover crop strategies are ranked one, two, and three. However, toward the risk-averse end of the spectrum, the conventional treatments 60N and 40N move up in the rankings. For interval 16, they are ranked two and three, respectively. Cumulatively, cover crop treatments are preferred across all 16 intervals, cover crop treatments are ranked one and two in 12 intervals and hold the top three spots for five intervals. Conventional practices 60N and 40N are never preferred over at least one cover crop practice (HV) and are ranked two and three in only one interval (16).

Table 3 also shows there are instances where adjacent intervals possess the same rankings. However, efforts to combine them cause Type II errors. Specifically, the rankings do not change between intervals 1 and 2, 3 and 4, 4 and 5, 8 and 9, 9 and 10, 11 and 12, and 13 and 14. In five of these instances, combining the intervals causes a lack of dominance between WH60N and 60N. The other two cause a lack of dominance between WH60N and 40N.

The space between intervals 1 and 2 was investigated to determine if the rankings change in this area. It was found that they do not. Furthermore, if $r2$ is held constant at $-.00002829$ (the $r2$ value of interval 2), an interval with no Type II errors may be defined between $r1 = -.00002998$ and $r2 = -.00002829$. The reason for this seems to be related to the fact that the cumulative distribution functions (CDFs) shown in figure 1 for WH60N and 60N cross six times (WH60N and 40N cross twice). This phenomenon is of minor practical significance because rankings do not change in this interval space regardless of which two intervals are used. Also, the risk premiums resulting from the different values of $r2$ in the first interval and $r1$ in the second interval vary by an average amount of only $5.51 per acre. Similar results are obtained from the other intervals where rankings do not change. Simply put, where rankings do not change between intervals, some variance in $r1$ and $r2$ values will occur depending upon whether the analysis starts at the risk-averse or risk-preferring end of the range.

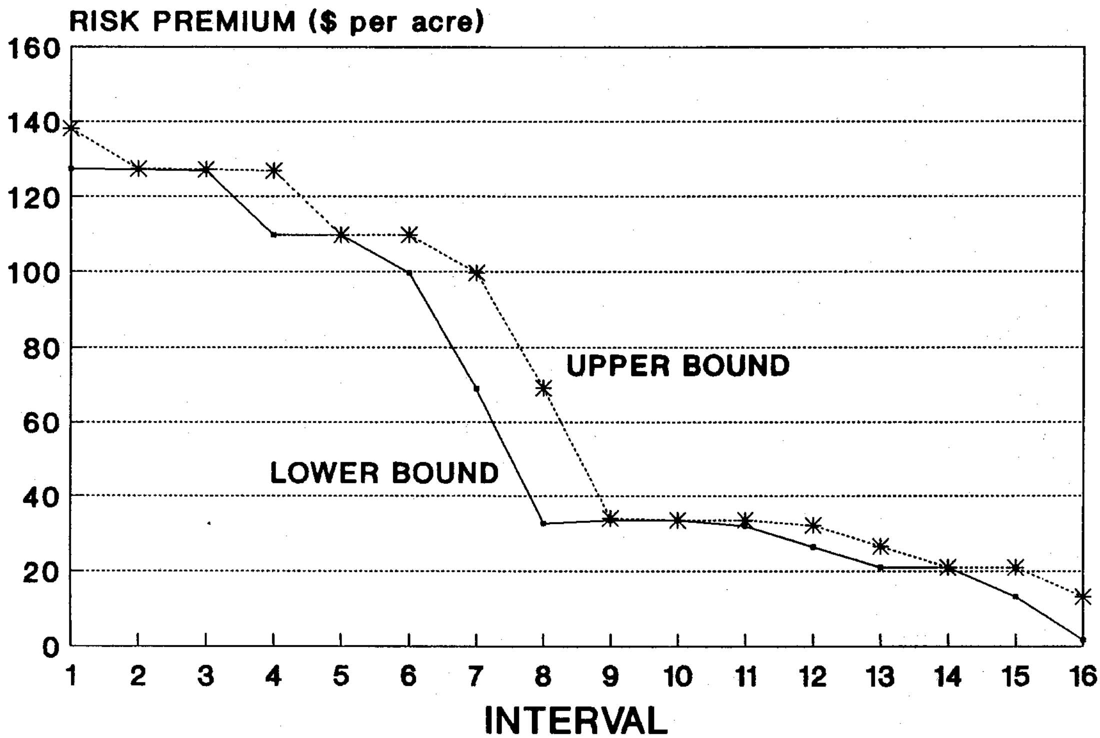

Figure 2. Lower and upper bounds on the risk premium between the highest ranked cover crop system and the highest ranked conventional system

The variance in *r*-values and inability to rank combined intervals may well be caused by numerical errors resulting from the fact that the two distributions cross frequently. Combining these intervals for the purpose of simplifying the results and presenting consolidated risk premiums would not alter findings, but might serve to obscure some of the difficulties encountered in this type of analysis.

Raskin and Cochran present a "Summary of Commonly Used Risk Aversion Coefficients" (their table 1, p. 205). Comparing the risk aversion coefficients delineated in this study to those in their table for either whole farm or annual income, it is evident that some are similar in magnitude while others are not. It should be noted that no two studies with different outcome scales and/or different distributions will produce the same risk aversion coefficients, whether elicited, assumed, or determined as in this study. But if the scales are approximately the same, coefficients should be in the same range. Those studies listed in Raskin and Cochran that used intervals in approximately the same range as this study include Zacharias and Grube, and King and Oamek.

Initially, the premiums were generated using whole farm net returns and *r*-values. They were then divided by the number of acres (415) in a representative farm to reflect per acre values (yielding premiums equivalent to those generated using per acre net returns and *r*-values).

Because a tabular listing of the risk premiums is quite lengthy and difficult to comprehend, the premiums between the highest ranked conventional and cover crop systems are graphically presented in figure 2. This figure illustrates the degree of dominance cover crop systems possess over conventional systems. The risk premiums between the highest ranked cover crop system and the highest ranked conventional system are given in figure 2 on an interval-by-interval basis. Intervals 1–6 show the premiums between VE40N and 40N. In interval 7, VE40N still dominates HV, but 40N ceases to dominate 60N; therefore, the premium shown in this interval is between VE40N and 60N. For intervals 8–16, HV dominates VE40N and 60N dominates 40N, so the premiums shown are between HV and 60N.

Figure 2 shows that two cover crop production systems, either HV or VE40N, are significantly dominant over the entire risk attitude spectrum. For the most risk-preferring group of decision makers, represented by interval 1, the lower (upper) bound on the risk premium is \$127.44 (\$138.09) per acre. Moving into a more risk-neutral area (interval 8), the lower bound premium is reduced to \$32.77 and the upper bound to \$69.06. For the most risk-averse interval (16), the lower bound on the premium is \$1.76, while the upper bound is \$13.23. Although the risk premiums decline with increasing decision maker risk aversion, they are substantial across the entire risk attitude spectrum.

That risk premiums decrease as the degree of risk aversion increases is in agreement with the progressively higher rankings shown in table 3 for conventional practices (40N and 60N) and provides an explanation as to why conventional practices have been so pervasive in cotton production. This statement is strengthened by the assumption of some degree of risk aversion on the part of many, if not most, agricultural producers. Although the results of this study show that HV is the dominant strategy over the range from mildly risk-preferring to extremely risk-averse (intervals 8–16), the decreasing risk premiums indicate that as risk aversion increases, the degree of HV's dominance over conventional practices diminishes considerably.

Limitations and Conclusions

This article presents a GSD evaluation of the relative economic feasibility of using alternative cover crop production systems, and compares them to two conventional practices in cotton production. Results show that, depending on the risk attitude of the decision maker, two cover crop strategies (HV and VE40N) are viable alternatives to conventional practices. This finding is contingent upon the invariance of the relative prices of the inputs varied between the systems. Similarly, wide variation (especially on the downside) in output prices also may change results; however, the current government program virtually negates this eventuality for practical purposes.

A limitation of this study concerns timeliness of field operations uncertainties—specifically, the consideration of additional production risk associated with cover crop production systems due to the minimum 10-day waiting period between when a cover crop is disked under and when cotton may be planted (Millhollon and Melville). This period, especially in the event of a wet planting season, could significantly affect net returns by negatively influencing the number of acres a producer is able to plant. To a lesser extent, adverse effects on timeliness of operations also may be present during the harvest season because of the increased demands cover crop systems place on a producer's limited stock of equipment, labor, time, and managerial skills.

A secondary limitation which could impede the adoption of cover crop systems is that they may reduce producer flexibility to plant crops other than cotton. Because the cover crop must be planted in the fall, it forces production decisions to be made over a longer time horizon (with inherently more unknown factors) relative to conventional systems. Should weather or market conditions dictate planting a different crop, there is no guarantee that the benefits of the cover crop (the cost of which must be treated as sunk at this point) will accrue to the alternative crop in the same manner they accrue to cotton.

Incorporation of historical, area-specific weather patterns in the budgeting process could help negate these limitations. Simulation of the stochastic variables influencing cotton growth, to account for delays in planting dates due to interactions between the weather and the 10-day waiting period, may provide additional information. Alternatively, altering the machinery and labor complements in the enterprise budgets associated with cover crops could help solve this problem, although it likely would increase the costs of cover crop systems. On the flip side of the coin, additional charges to account for increased environmental impacts associated with conventional systems may make cover crop production systems more attractive.

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Notes

[1] Sometimes referred to as the Pratt–Arrow risk aversion coefficient.

[2] This paragraph draws substantially on Lee, Ellis, and Lacewell, and on Cochran and Raskin. A more comprehensive mathematical treatment may be found in Kramer and Pope.

[3] AWP was dropped because its mean and standard deviation were nearly identical to 40N. Had it been included, the result would have been a significant increase in the number of intervals, with little increase in the quality of information. Although AWP's mean was $.20 per acre greater than 40N's, it also had much lower minimum and maximum values. Only a risk-neutral (interval 8) decision maker would rank AWP higher than 40N. Therefore, it never could be ranked higher than fifth. CV was not included because it was suspended from the cover crop study in 1985.

[4] The percentages used were 34.3% and 65.7% of seed cotton yield for lint and cottonseed, respectively.

[5] Those treatments exhibiting significant trends in the linear analysis were HV (*t*-statistic 2.4934) and CHECK (*t*-statistic −2.8248). In the nonlinear analysis, only CHECK had a significant trend (*t*-statistic −2.9037).

[6] Input costs differ due to variations in cover crop seed costs, cover crop planting costs, and fertilizer costs among treatments.

[7] Following Goh et al., the formula for the relative risk aversion coefficient (*rrac*) is $rrac = r \cdot x$, where the maximum possible value of *rrac* equals 100, r is the calculated Pratt risk aversion coefficient, and x equals the value of the highest observation in any of the comparison distributions ($666.45 in this case). Although recent improvements in compilers may make it possible to exceed an *rrac* value of 100, this is sufficient to capture essentially all rational behavior. Limiting *rrac* to 100 did not affect the accuracy of the analysis.

[8] There is no particular significance attached to the calculated Pratt risk aversion coefficient. It is simply the greatest absolute value allowed by the program for this specific data set.

[9] This procedure is similar to McCarl's breakeven risk aversion coefficient (BRAC) identification procedure.

[10] Converting from per farm back to per acre is exactly the opposite. Simply divide returns by 415 and multiply all Pratt risk aversion coefficients by 415.

[11] The difference between the per acre intervals is .000001 (which was sufficient to eliminate Type II errors), but the difference between per farm intervals is .00000001. When .000001 is divided by 415, the quotient is smaller than .00000001, but eight decimal places was sufficient to eliminate all Type II errors. Therefore, there was no need for further specification.

[12] The risk premiums may vary by approximately $1 per acre due to rounding errors.

[13] The reduction in intervals occurred because there are three whole farm intervals (5, 10, and 14) where $r1$ equals $r2$. Each of these were two separate intervals in the per acre analysis (at six decimal places), but they had the same rankings. They were consolidated in the whole farm analysis because the r-values were carried out only enough to eliminate Type II errors; i.e., if the whole farm analysis were carried out to more decimal places, these intervals would be divided, but rankings would not change between them.

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