Soil Health and Economic Risk: Observed and Modeled Assessments

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Farmers contend not only with uncertainty due to seasonal changes in growing conditions affecting crop yield, but from changes over time in both input costs and prices received. Accordingly, reducing the probability of an undesirably low revenue, or risk can be challenging because so many factors contribute to farm profitability. The use of soil health promoting practices (SHPPs) like reduced tillage, cover crops, and crop rotation may alter both crop yield and the amounts and types of inputs required. Because yield and input costs dramatically impact revenue, it is important to know how different farming strategies can impact a producer's bottom line. The question we sought to answer was: Do SHPPs affect profitability and risk? In other words, do these practices pay for themselves? Contribution Margin (CM) was concluded to be a useful indicator to provide an answer for this question.

Contribution margin is calculated as the sales revenue minus variable costs. In risk analyses, CM can be used in two ways, among others:

1) Standard deviation: the standard deviation of a set of outcomes (e.g. CM) measures the possible dispersion of outcomes. A higher CM standard deviation over the years under one practice than another can portray a higher level of risk, if mean yields are equal.

2) Downside Risk: measured either as the number of years for which returns are below a target, or the negative deviations from a target. Downside risk is related to loss exposure – if there are more total negative earnings for one practice versus another, then that particular undertaking is more risky.

This analysis focused on these two indicators as measurements of risk. The objective was to quantify and communicate the impacts of soil health management systems on economic risk and profitability in agricultural production practices. These practices are no-till, conservation tillage, cover crops, and crop rotation.

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STUDY METHODOLOGY

Data sources. Both observed and modeled contribution margins were obtained from peer-reviewed and land grant university extension literature sources. Observed data was extracted from 22 articles explicitly covering the economics of either cover crop use, reduced tillage, or crop rotation compared to continuous cropping. Each study was based on either individual field studies or observed field-level data for working farms in a particular region. Information returned from the studies included crop species, farming practice, total revenue and variable costs, or those excluding fixed costs on machinery, depreciation, land, and overhead. Variable costs and total revenue must have been reported on a per area basis.

Modeled contribution margin was calculated using a subset of the data used in the yield variability analyses. These comprised 85 studies total. These data were the location, crop, yield, year, and farming practice compared for each of the comparisons of no-till vs. conventional tillage, no-till vs. conservation tillage, conservation vs. conventional tillage, as well as for a composite of any tillage vs. no-till. Individual crop price data was obtained from USDA databases available online. Contribution margins were determined for each year by crop by location by tillage practice combination using the observed yield data and the estimated USDA variable cost data and price received for the same crop and year. The USDA reports this data irrespective of tillage practice or region within the U.S.

These modeled data were used to determine the CM mean and standard deviation for each crop and practice. Observed data were used not only to determine CMs for each crop and practice, but also to perform t-tests for a difference in mean CM for no-till vs. conventional tillage, no-till vs. conservation tillage, conservation vs. conventional tillage, as well as for the composite of any tillage vs. no-till. These statistical significance tests are commonly used in this kind of analysis comparing different practices.

Standard deviation. The standard deviation (s) is used here as a measure of contribution margin variability across the years of data at a given site.

Downside risk. This was calculated as the probability that CM would be less than 0 among the modeled CM data. Assuming normally distributed data over the years of each experiment, probabilities were calculated using R statistical language's "pnorm" function, which is the equivalent of using a Z-table. Values are expressed as probabilities.

RESULTS AND DISCUSSION

Contribution margin means. The t-test results displayed below indicate that CM means are not statistically different between any comparison of tillage practices or for cover crops or rotation vs. their alternatives (Table 1, Table 2). These results suggest, that the revenue left to pay fixed costs does not differ universally between farming practices. Of course, at individual research locations, CM was either numerically lower or higher under the SHPP than the conventional practice. Multiple factors likely are involved in determining whether SHPPs save or cost more money at a given location. We also examined the differences in CMs between SHPP and control by crop, but this also did not reveal any differences (Table 3).

Table 1 Test results for differences in contribution margin between SHPPs and controls, from observed economic data

SHPP vs. control comparison	Number of studies	Control	SHPP	95% confidence interval[1]	*p* value[2]
		Contribution margin, $ ac^{-1}			
Conservation tillage vs. conventional tillage	14	122	125	-14 to 9	0.64
No-till vs. conservation tillage	7	119	117	-13 to 17	0.77
No-till vs. conventional tillage	11	92	88	-8 to 17	0.44
No-till vs. any tillage	18	102	99	-5 to 12	0.41
Cover crop vs. no cover crop	2	157	162	-457 to 447	0.91
Rotation vs. continuous planting	4	76	83	-71 to 58	0.76

1. 95% confidence interval of the difference between control and SHPP contribution margins. Negative values indicate SHPP CM is larger than control CM.
2. *p* value of a *t*-test that the true difference in contribution margin means is not 0.

Table 2 Test results for differences in contribution margin between SHPPs and controls, from observed economic data, by crop

Comparison	Crop	Number of studies	Control	SHPP	95% confidence interval[1]
			Contribution Margin, $ ac^{-1}		
Conservation tillage vs. conventional tillage	Corn	5	108	108	-11 to 11
	Cotton	2	261	220	-104 to 186
	Soy	4	110	110	-6 to 7
	Wheat	2	102	124	-229 to 186
No-till vs. conservation tillage	Corn	3	101	98	-26 to 33
	Soy	2	116	113	-67 to 72
No-till vs. conventional tillage	Corn	4	86	81	-25 to 34
	Soy	3	94	100	-28 to 17
	Wheat	2	71	43	-190 to 247
No-till vs. any tillage	Corn	7	92	88	-10 to 18
	Cotton	2	238	229	-179 to 197
	Soy	5	103	105	-13 to 9
	Wheat	3	62	52	-79 to 99

1. 95% confidence interval of the difference between control and SHPP contribution margins

Table 3 Test results for differences in contribution margins between SHPPs and controls, from modeled economic data

Comparison	Crop	Number of studies	Control	SHPP	95% confidence interval[1]
			Contribution Margin, $ ac⁻¹		
Conservation tillage vs. conventional tillage	Corn	25	233	244	-106 to 82
	Soy	8	154	156	-53 to 49
	Wheat	10	155	152	-121 to 128
	Corn	37	146	139	-75 to 89
No-till vs. conservation tillage	Soy	7	165	165	-45 to 44
	Wheat	18	151	154	-96 to 90
No-till vs. conventional tillage	Corn	33	185	214	-107 to 49
	Soy	11	146	148	-39 to 34
	Wheat	14	164	166	-110 to 108
No-till vs. any tillage	Corn	51	133	135	-65 to 61
	Soy	13	149	148	-32 to 35
	Wheat	24	155	158	-81 to 77
	Corn	25	233	244	-106 to 82

1. 95% confidence interval of the difference between control and SHPP contribution margins

Various factors could explain the lack of difference in mean contribution margins between SHPPs and their controls. Conservation tillage is a broad category including ridge, mulch, strip, subsoiler, and chisel tillage, among others. All of these practices carry different input costs and may be difficult to categorize altogether. Nevertheless, it is not possible to control for the influence of tillage type within the overall conservation tillage class without more economic or yield data for each type of practice. Further, CM averages across time don't capture the results in terms of risk of switching from one practice to another. While the modeled data address this risk element, they do not capture differences in variable costs that may exist between practices. In addition, one of the benefits that some farmers attribute to cover crops is their ability to buffer yields in dry seasons, thereby providing less risk to yields under drought. The studies used in this analysis often did not account for seasonal variability in weather, precluding an analysis of the relationship between such parameters and risk.

Contribution margin risk. As an indicator of risk, standard deviation of CM provides strength to this analysis, as this addresses economic performance in the long run. These data show the long-term variability in CM among the observed data, which captures variation in not only crop yield, but also crop price and variable costs. Contribution margin variability over time decreases in the order corn > wheat > soy. This is likely due simply to corn having higher yields and higher revenue. Values of CM were similar for both reduced and more intensive forms of tillage, however. Neither the SHPP nor the control was consistently more variable than its counterpart.

Table 4 Contribution margin variability by tillage treatment and crop, from modeled data

	Conservation vs. Conventional Tillage	No-till vs. Conservation Tillage	No-till vs. Conventional Tillage	No-till vs. any Tillage
	Standard deviation in contribution margin, \$ ac^{-1} (SHPP, Control)			
Corn	131, 133	117, 109	121, 123	108, 104
Soy	80, 82	86, 83	78, 83	78, 79
Wheat	100, 88	87, 86	96, 88	84, 82

Lastly, we calculated downside risk, or the probability of a contribution margin leaving no revenue to apply to fixed costs. Downside risk was similar for all tillage systems compared (Table 5). It is interesting to note that corn crops often result in higher downside risk, possibly due to a combination of yield variability and high variable costs. Over the period 1975-2016, variable costs were \$176, \$85, and \$68 for corn, soy and wheat respectively. The data show soy to be less risky in terms of negative contribution margin than either corn or wheat (Table 5).

Table 5 Probabilities of negative contribution margin by crop and treatment, from modeled data

	Conservation vs. Conventional Tillage	No-till vs. Conservation Tillage	No-till vs. Conventional Tillage	No-till vs. any Tillage
	Probability of contribution margin < 0 (SHPP, Control)			
Corn	0.11, 0.10	0.22, 0.27	0.15, 0.13	0.22, 0.26
Soy	0.04, 0.04	0.04, 0.04	0.05, 0.06	0.04, 0.05
Wheat	0.14, 0.13	0.13, 0.12	0.13, 0.11	0.11, 0.10

SUMMARY AND RESEARCH PRIORITIES

While this work provides estimates of differences between SHPP and control contribution margins (CM), the estimates of temporal variation in CM for the various tillage treatments rely on modeled cost data. A primary issue is the lack of availability of input costs for no-till as well as specific conventional and conservation tillage practices. Additional efforts should be made to compile accurate information such as fuel, chemical application, and machinery costs that would differ greatly among tillage practices.

As is typically the case with work reviewing the status of findings in a given field, the same methods could be applied to a larger dataset than is currently available. This would make conducting more powerful tests possible, especially for comparisons for which data were most lacking. Specifically, additional input cost and revenue data is needed for alternative rotations and cover crops.

Overall, the results of this analysis indicate that there is no statistically significant difference between the contribution margins associated with the three soil health practices or their controls. While we can observe differences in mean, standard deviation, and coefficient of variation as shown above, the statistical tests indicate that the differences are not significant.

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