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Annual Net Returns to Cover Crops in Iowa

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Cover Page Footnote
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ABSTRACT

Despite the active promotion of cover crops as a key conservation practice, their adoption is very limited. We developed a series of partial budgets based on a statewide survey of Iowa farmers to evaluate the changes in net returns resulting from the incorporation of cover crops into a corn or soybean production system. The average net returns to cover crop use for farmers who did not use cover crops for grazing livestock or forage were consistently negative across different planting and termination methods, tillage practices, and experience levels. Only farmers who used cover crops for grazing livestock or forage and received cost-share payments tended to derive net positive returns from cover crop use. Our results can be used as benchmarks for current or potential cover croppers and for ground-truthing agricultural and conservation policy design.

KEYWORDS

cover crops, partial budget, net returns, cereal rye, Iowa

INTRODUCTION

Cover crops are scarcely adopted in Iowa despite their soil health and environmental benefits[1] and the array of cost-share programs available to farmers. In 2012, the Natural Resource Conservation Service (2012) estimated that only 100,000 out of 30 million acres of farmland in Iowa were planted to cover crops. Five years later, the same agency estimated that with financial assistance from numerous cost-share programs,[2] cover crop acreage only increased to 353,000 in 2016 (Natural Resource Conservation Service, 2017). Using satellite imagery, Rundquist and Carlson (2017) reported that in 2015, cover crops were incorporated into only 2.65% of corn and soybean rotations in Iowa.

A major barrier to adoption of new agricultural practices is the lack of familiarity with novel approaches (Nassauer et al., 2011). For example, across four surveys (Watts & Myers, 2013, 2014, 2015, and 2016), farmers reported that the greatest challenges to using cover crops were species selection, plant establishment failure, time or labor required, and increased management. Another major barrier is farmers' perception that cover crops are costly: 74% of the respondents to the Iowa Farm and Rural Life Poll (Arbuckle, 2015) reported that potential economic impacts had moderate to very strong influence on changes in their management practices, and 57% agreed with the statement that "pressure to make profit margins makes it difficult to invest in conservation practices." Roesch-McNally et al. (2017) found that even successful cover crops adopters tended to believe that greater economic incentives would be needed to spur further adoption of the practice.

However, only a few studies have analyzed the economic impacts of cover crop adoption in U.S. row crop agriculture. Reddy (2001), Mahama et al. (2016), and Roberts et al. (1998) used field experimental data to assess the economic returns to cover crops in Mississippi, Kansas, and Tennessee, respectively. Nevertheless, their conclusions were based on field experiments and might not apply to real farms where management practices do not follow an experimental design.

Using actual data from 15 corn producers in Michigan, Roberts and Swinton (1996) concluded that cover crops do not significantly reduce net returns. However, the small sample size limits the robustness of their results.

Based on focus group discussions, Snapp et al. (2005) and Roesch-McNally et al. (2017) provided qualitative summaries of the potential benefits and

costs from cover crops to Michigan potato farmers and Iowa row crop farmers, respectively.

Finally, Plastina et al. (2018) developed partial budgets using survey data from midwestern farmers and concluded that average net returns to cover crops were negative when cover crops were followed by corn but positive when cover crops were followed by soybeans. However, the sample size and the wide geographical dispersion of the respondents (79 farms across 11 states) limit the robustness of their results.

The present study contributes to the existing literature by providing the most robust analysis to date of the net returns to cover crops in midwestern row crop production. We apply the methodology developed by Plastina et al. (2018) to a much larger sample of Iowa farms and calculate partial budgets for various combinations of cover crop mixes and management practices. We find that cover crops generate consistent negative net returns when not used for grazing livestock or forage. Only farmers who use cover crops for grazing livestock or forage and who also receive cost-share payments tend to obtain positive net returns from cover crops.

The rest of the essay is organized into a methodological section, followed by a results section and a concluding section briefly discussing the implications of our findings for farm operators and policy makers.

METHODOLOGY

Survey Questionnaire

The survey instrument was designed based on focus group discussions with farmers with at least three years of experience with cover crops in Iowa, Minnesota, and Illinois and was modified based on a follow-up pilot survey implemented among focus group participants (Plastina et al., 2018). The final survey questionnaire consisted of 192 questions organized in seven sections: basic farm information, cover crop planting, cover crop termination, revenues and costs, tillage, previous rotation, and perceptions about cover crops.

The strategy to identify differences across production systems with and without cover crops was to ask respondents to characterize their production system with cover crops first and then to ask them whether such characteristics also applied to their production system without cover crops over the same period of time. There are two major reasons to believe that our strategy is better than directly asking farmers to provide dollar values for overall changes in costs and revenues induced by cover crops. First, the questions expose all participants to the same detailed list of possible changes in practices that might affect cash flows and opportunity costs, improving the comparability of answers across respondents. Second, the questions were specifically designed to induce respondents to make comparison across systems (with and without cover crops) over the same period of time so as to minimize the effects of external factors (such as weather, soil conditions, years of experience with cover crops, and macroeconomic conditions) on partial budgets.

Cash costs (including seed costs, fertilizer costs, herbicide costs, and custom hired work) and cost-share payments[3] received by farmers were directly identified through questions that asked producers to report dollar values.

The survey did not ask farmers to come up with own machinery costs per acre. Instead, the survey asked farmers to report the machineries they used to plant and terminate cover crops. Then, we imputed machinery costs (including fuel, repair and maintenance, labor, depreciation, property taxes, housing costs, interest, and insurance) for each respondent based on the cover crops budgeting tool developed by Cartwright and Kirwan (2014). The hourly rate for labor was set at $13, close to the regional average wage rate for fieldworkers in the Cornbelt reported by the National Agricultural Statistics Service (NASS 2015).

To estimate the opportunity costs of added management per acre due to the use of cover crops, the survey asked for an estimate of total additional management hours on top of the respondent's typical management hours for a system without cover crops. Then, the number of additional hours was multiplied by an hourly rate of $15 and divided by the total cover crop acres planted in 2015. To estimate changes in revenue due to yield differences across fields with and without cover crops for the same farmer, prices of $4 per bushel of corn and $10 per bushel of soybeans were used in the calculations.

Survey Sample

A stratified random sample of 1,250 operators in the state of Iowa was identified by the Upper

Midwest regional office of NASS, based on the population of farmers who reported planting at least 10 acres of cover crops in rotation with row crops in farms of at least 50 cropland acres in size in the 2012 U.S. Census of Agriculture. Row crop farming rotations were defined for this study as including corn, soybean, and wheat (i.e., excluding fruits, vegetables, tree nuts, greenhouse, nursery and floriculture production, tobacco, cotton, etc.). The sampling strategy accounted for farm sizes (small, medium, and large) and geographical coverage across the state.

The survey questionnaire was mailed on February 1, 2017, and a second questionnaire mailing was sent to all nonrespondents by mid-February. Finally, telephone follow-ups of nonrespondents were conducted.

Despite its geographical coverage and the detailed criteria followed in developing the random sample by NASS, the sampling framework (which excluded operators who adopted cover crop use after 2012 and included operators who discontinued the use of cover crops or retired after 2012) does not allow us to make any inferences about population totals or averages. However, our results are the best estimates of net returns to cover crops available in the literature due to both the partial budget approach used in the calculations and the sample size of nonexperimental field data.

A total of 674 responses were received, amounting to a 54% response rate, of which 440 corresponded to operators who had planted cover crops and 234 corresponded to operators with no cover crops experience.[4] The data used for the present study correspond to the subset of operators who planted cover crops in 2015 in some of their acres (but not all) and planted the same cash crop in 2016 both in acres following cover crops and in acres without cover crops. A total of 233 responses distributed across all agricultural districts (Figure 1) were left after excluding responses from (1) farmers with no cover crops experience, (2) farmers who did not plant cover crops in 2015, (3) farmers who planted cover crops in 2015 on all of their acres, (4) farmers who in 2016 planted a different cash crop on acres following cover crops than on acres left fallow during winter, and (5) incomplete responses. This selection process reduces the sample size but improves the validity of the results by focusing on the changes in costs and revenues associated with cover crop use, controlling for the farm manager effect and the macroeconomic conditions prevalent in 2015–2016.

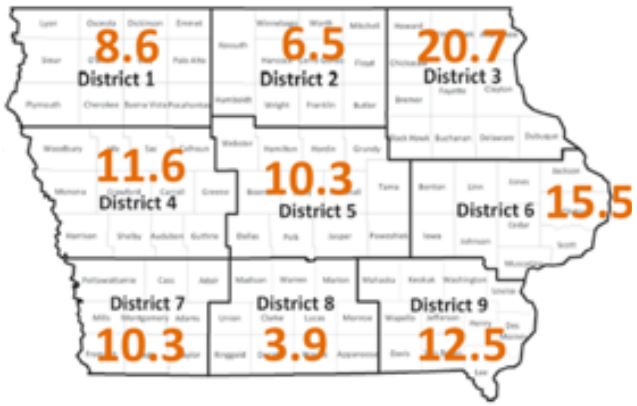

Figure 1. Distribution of Respondents Who Planted Cover Crops in 2015 by Agricultural District

Partial Budgets

Partial budgets capture the net annual economic benefit or loss associated with the use of cover crops by identifying and monetizing the differences in management practices across production systems with and without cover crops (Kay, Edwards, & Duffy, 2016). For each farm operator, expenses and revenues in his or her production system with cover crops are compared against expenses and revenues in his or her production system without cover crops. The main sources of changes in revenue due to cover crop use are changes in the value of production of the following cash crop, cost-share payments received by farmers, savings in livestock feed costs from grazing cover crops, and the net returns to harvesting cover crops' biomass for forage.

The major sources of changes in costs due to cover crop use can be split into planting, termination, and other costs. Planting costs depend on seed costs, planting method (drilling, aerial, broadcasting, etc.), and whether the planting was done by the operator or was custom hired. Termination costs depend on the method used to terminate cover crops (herbicide, tillage, winter kill, mowing, etc.), whether the work was done by the operator or was custom hired and whether

the method is differentially applied to acres with cover crops but not on acres without cover crops. When the method used to terminate cover crops is part of the typical spring management practices used by a farmer across all acres (with and without cover crops), the extra costs to terminate cover crops tend to be lower than when the termination method is only applied on acres with cover crops. For example, if an operator applies one pass of preplant burndown across all acres (with and without cover crops) but the herbicide dose for the acres with cover crops is more concentrated than in the acres without cover crops, then the termination costs used in the partial budget for this operator amount only to the difference between the cost of the more concentrated herbicide mix and the cost of the less concentrated mix per acre. If another operator does not apply a preplant spring treatment in the acres without cover crops but applies one field pass of herbicides to terminate cover crops, then the entire cost of the herbicide mix plus the application cost (fixed and variable costs of machinery use and operator's time) is included in the partial budget for that operator.

Other sources of changes in costs targeted by the survey questionnaire include cash crop seed costs; cash crop planting costs (excluding seeds); nitrogen (N), phosphorous (P), potassium (K), manure, insecticide, fungicide, and soil testing costs; costs to repair soil erosion; opportunity cost of extra management time; and changes in cash rent paid due to cover crop use.

RESULTS

The average area planted to cover crops in 2015 by our survey respondents amounted to 268 acres, or about 21% of their farmland (Table 1). Respondents had on average 7.9 years of experience with cover crops. However, half (two-thirds) of them had 6 (8) years of experience or less. The cumulative number of cover crop acres planted through all the years of experience averaged 870 acres per operator. Eighty-three percent of the respondents operated farms between 200 and 2,000 acres in size, and the median farm size was 500–999 acres (Table 2). The most frequently planted cover crop among our survey respondents was cereal rye (typically by itself and to a lesser extent mixed with oats), followed in a distant second place by annual ryegrass. The most extensively used planting method[5] was drilling (76%), followed by aerial and broadcast seeding (19% and 4%, respectively). Two-thirds of the respondents used herbicides to terminate cover crops, and the other third chose tillage, mowing, or winter kill as the termination method. Three in five respondents planted corn[6] for grain or seed following cover crops, while the other cover croppers typically planted soybeans[7] in 2016.

The partial budget results are presented in sets to sequentially discuss the overall net returns to cover crops in Iowa and the effects of experience, tillage method, planting method, and termination method on net returns to cover crops. To obtain robust estimates of each of the items included in the partial budgets, all valid responses were used in the calculation of the reported summary statistics: mean, median, and range. The downside to this approach is that subtotals and totals do not reflect the actual changes in costs, revenues, or net returns for any producer in particular but instead reflect the measures of central tendency across sources of changes in net profits.

Table 1. Characteristics of Operators Surveyed

Variable	Mean	Median	Range	#Obs.
Acres of cover crops planted in fall 2015	268	80	[5, 7500]	227
Total number of acres planted to cover crops since starting to use cover crops	870	360	[4, 10000]	230
Number of years of experience with cover crops	7.9	6	[1, 45]	233
Estimated percentage of operator's land on which cover crops were planted in fall 2015*	21%	12%	[.33%, 100%]	223

* Reported cover crop acres divided by the midpoint of the range for the corresponding farm size category, censored at 100%.

Table 2. Survey Responses by Farm Size, Cover Crop Species, Planting Method, Termination Method, and Following Cash Crop

Farm Characteristic	#Obs.	Percent
Farm size		
1–49 acres	1	0.43
50–99 acres	1	0.43
100–199 acres	14	6.03
200–499 acres	54	23.28
500–999 acres	76	32.76
1,000–1,999 acres	63	27.16
2,000 acres or more	23	9.91
Total	232	100
Cover crop species		
Cereal rye	164	71.00
Cereal rye + oats	11	4.76
Annual ryegrass	12	5.19
Annual ryegrass + crimson clover + oilseed radish	3	1.30
Annual ryegrass + crimson clover + oilseed radish + rapeseed	2	0.87
Oats + oilseed radish + buckwheat	1	0.43
Oats + oilseed radish + turnip	4	1.73
Other	34	14.72
Total	231	100
Planting method		
Aerial seeding	40	18.87
Broadcast seeding	9	4.25
Drilling	161	75.94
Other	2	0.94
Total	212	100
Termination method		
Herbicide	154	66.38
Tillage	36	15.52
Mowing	21	9.05
Winter kill	18	7.76
Other	3	1.29
Total	232	100
Following cash crop		
Corn for grain or seed	135	58.70
Soybeans	87	37.83
Oats for grain	1	0.43
Other	7	3.04
Total	230	100
Hired custom planting of cover crops		
Yes, for all acres	69	30.00
Yes, for some acres	24	10.43
No	137	59.57
Total	230	100

Net Returns to Cover Crops Terminated With Herbicides

The average calculated changes in net returns stemming from the use of cover crops terminated with herbicides across all cover crops, all planting methods, and all tillage methods were positive: $8.59 per acre for cover crops followed by corn (Table 3) and $14.25 per acre for cover crops followed by soybeans (Table 4). However, those averages include in their calculations the cost savings in livestock feed from farmers who use cover crops for grazing or forage: an average of $35 per acre for cover crops followed by corn across 9 farms and $32.54 per acre for cover crops followed by soybeans across 13 farms. When those cost savings in livestock feed are excluded from the calculations, the resulting changes in net returns average losses of $26.41 for cover crops followed by corn and $18.29 for cover crops followed by soybeans.[8] Furthermore, the net returns to cover crops in the absence of both savings on livestock feed and cost-share payments[9] average net losses of $48.82 for cover crops followed by corn and $38.42 for cover crops followed by soybeans. Finally, the average reduction in yields following cover crops (comparing yields across a field with cover crops and another similar field without cover crops operated by the same farmer) was 2 bushels for corn and 0.1 bushel for soybeans. Although the median yield differences were null in Tables 3 and 4, the same qualitative results are derived when analyzing median changes instead of average changes in net returns due to cover crop use.

The major cost drivers in Tables 3 and 4 are planting costs, which add up to $33 per acre, composed in nearly equal parts of seed costs and planting costs (excluding seeds). It is interesting to note that the reported rates paid to hire custom planting of cover crop seeds come very close on average to the calculated costs of using farmers' own planting machinery based on Cartwright and Kirwan (2014).

Termination costs depend on whether the operator sprays all of his or her acres with herbicides as part of the preplant treatment. About 80% of the farmers in Tables 3 and 4 applied a preplant burndown across all their acres, and their extra herbicide costs (on top of the typical preplant

Table 3. Overall Changes in Net Returns Due to Cover Crop Use Followed by Corn, for All Cover Crop Species, All Planting Methods, Terminated With Herbicides

Sources of Changes in Net Profits	Mean	Median	Range	#Obs.
		$/acre		
A. Changes in revenues				
1. Cost-share program	22.41	20.00	[5; 80]	39
2. Value of change in following corn yield*	–8.06	0.00	[–108; 80]	69
3. Savings or extra revenue from grazing or harvesting cover crop for forage	35.00	22.00	[3; 100]	9
Subtotal A. Changes in revenue	***49.35***	***42.00***		
B. Changes in costs				
1. Cover crop planting				
a. Seeds	17.70	16.00	[5; 47]	76
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	14.82	16.15		
i. Custom work	14.39	15.00	[4; 30]	41
ii. Noncustom	15.14	16.99	[2.42; 25.33]	56
Subtotal B.1	*32.52*	*32.15*		
2. Cover crop termination				
a. Extra expenses for farmers who applied herbicides to all acres (with and without cover crops)	8.07	0.00		68
i. Extra herbicide cost on top of regular weed control program	0.56	0.00	[0; 17]	68
ii. Extra labor costs to apply herbicides on top of regular weed control program^	5.54	0.00	[0; 130]	68
iii. Other termination expenses	1.97	0.00	[0; 40]	68
b. Extra expenses for farmers who did not apply herbicides before planting corn in acres without cover crops	16.82	15.54		16
i. Herbicide cost to terminate cover crops	9.50	8.00	[4; 24]	16
ii. Herbicide application cost. Weighted average of custom and noncustom work.	7.32	7.54	[3.06; 15.4]	
1. Custom work	14.20	14.00	[6; 30]	5
2. Noncustom	5.02	5.38	[2.08; 10.53]	15
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*9.74*	*2.96*		
3. Changes in other costs~				
a. Nitrogen costs	–0.18	0.00	[–20; 5]	83
b. Manure costs	–0.09	0.00	[–10; 2.5]	83
c. Insecticide costs	–0.11	0.00	[–12; 3]	83
d. Fungicide costs	–0.13	0.00	[–14; 3.5]	83
e. Soil testing costs	–0.14	0.00	[–16; 4]	83
f. Costs to repair soil erosion	–0.16	0.00	[–18; 4.5]	83
g. Change in cash rent due to cover crop use	–0.68	0.00	[–20; 0]	44
Subtotal B.3	*–1.50*	*0.00*		
Subtotal B. Changes in costs	***40.76***	***35.11***		
C. Net change in profits (C = A – B)	***8.59***	***6.89***		
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–26.41***	***–15.11***		

* Reported changes in corn yields following cover crops due to cover crop use ranged from –27 to 20 bushels per acre, with an average loss of 2 bushels. The median farmer reported no change in corn yields.

^ Reported changes in labor hours per acre to terminate cover crops with herbicides ranged from 0 to 10 hours and averaged 0.43 hours. The median farmer reported no extra labor to terminate cover crops.

~ No respondent indicated changes in cash crop seed costs, cash crop planting costs (excluding seeds), P and K costs, or management time due to cover crop use.

Table 4. Overall Changes in Net Returns Due to Cover Crop Use Followed by Soybeans, for All Cover Crop Species, All Planting Methods, Terminated With Herbicides

Sources of Changes in Net Profits	Mean	Median	Range	#Obs.
		$/acre		
A. Changes in revenues				
1. Cost-share program	*20.13*	15.00	[7; 46]	23
2. Value of change in following soybean yield*	*–1.07*	0.00	[–100; 50]	56
3. Savings or extra revenue from grazing or harvesting cover crop for forage	*32.54*	20.00	[2; 150]	13
Subtotal A. Changes in revenue	***51.60***	*35.00*		
B. Changes in costs				
1. Cover crop planting				
a. Seeds	*16.34*	15.00	[2; 50]	50
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	*16.47*	16.95		
i. Custom work	*16.52*	16.00	[6; 32]	21
ii. Noncustom	*16.45*	17.47	[3.59; 24.17]	38
Subtotal B.1	*32.81*	*31.95*		
2. Cover crop termination				
a. Extra expenses for farmers who applied herbicides to all acres (with and without cover crops)^	*2.63*	0.00		49
i. Extra herbicide cost on top of regular weed control program	*0.29*	0.00	[–11; 12]	49
ii. Extra labor costs to apply herbicides on top of regular weed control program	*1.33*	0.00	[0; 39]	49
iii. Other termination expenses	*1.02*	0.00	[0; 20]	49
b. Extra expenses for farmers who did not apply herbicides before planting soybean in acres without cover crops	*18.54*	14.55		9
i. Herbicide cost to terminate cover crops	*11.56*	10.00	[2; 30]	9
ii. Herbicide application cost. Weighted average of custom and noncustom work.	*6.99*	4.55	[4.16; 13.53]	
1. Custom Work	*13.67*	8.00	[8; 25]	3
2. Noncustom	*4.48*	3.25	[2.72; 9.23]	8
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*5.10*	*2.26*		
3. Changes in other costs~				
a. Cash crop seed costs	*–0.18*	0.00	[–11; 0]	61
b. Costs to repair soil erosion	*–0.02*	0.00	[–1; 0]	61
c. Change in cash rent due to cover crop use	*–0.37*	0.00	[–10; 0]	27
Subtotal B.3	*–0.57*	*0.00*		
Subtotal B. Changes in costs	***37.34***	***34.21***		
C. Net change in profits (C = A – B)	***14.25***	***0.79***		
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–18.29***	***–19.21***		

* Reported changes in soybean yields following cover crops due to cover crop use ranged from –10 to 5 bushels per acre, with an average loss of 0.11 bushels. The median farmer reported no change in soybean yields.

^ Reported changes in labor hours per acre to terminate cover crops with herbicides ranged from 0 to 3 hours and averaged 0.10 hours. The median farmer reported no extra labor to terminate cover crops.

~ No respondent indicated changes in soybean planting costs (excluding seeds); N, P or K costs; manure, insecticide, fungicide, or soil testing costs; or management time due to cover crop use.

burndown) to terminate cover crops averaged less than $1 per acre. The reported extra termination costs for these farmers were related to higher concentrations of active ingredients or in some cases an extra field pass when the first herbicide application was not effective to fully terminate the cover crop. However, note that the median extra termination costs for this group of farmers are null in Tables 3 and 4.

For the minority of farmers who do not apply herbicides as part of their preplant program, termination of cover crops with herbicides represents a major additional expense: $16.82 for cover crops followed by corn and $18.54 for cover crops followed by soybeans, on average. Furthermore, for the subset of farmers who custom hire the termination of cover crops with herbicides, the average custom rate paid is nearly three times the cost of using their own sprayers.

Finally, while farmers who planted cover crops followed by corn experienced on average small savings in nitrogen, manure, insecticide, fungicide, soil testing, and soil repair costs and cash rents due to cover crop use, some farmers experienced large cost savings, while others experienced increases in those categories (see the ranges in Table 3). However, the median change in cost in all "other costs" categories was null. Similarly, the average changes in other costs for operators who planted cover crops followed by soybeans were small, and the median changes were null (see Table 4).

Net Returns to Cover Crops by Years of Experience

To explore the relationship between years of experience with cover crops and net returns, we developed partial budgets across all cover crop species terminated with herbicides and followed by corn production, across all planting and tillage methods, for operators with (a) up to 3 years of experience, (b) 4 to 9 years of experience, and (c) 10 or more years of experience. The average values for the relevant farmers in each category are shown in Table 5. While the average yield drag on corn production due to cover crops was smaller for farmers in (b) than for farmers in (a) (–0.1 bushels versus –5 bushels), and farmers in (c) experienced an average 0.5 bushel increase in yields due to cover crops, the net returns to cover crops excluding savings in livestock feed due to grazing or forage were negative for all experience levels. The average changes in net returns due to cover crop use followed by corn for operators in (a), (b), and (c) amounted, respectively, to –$37.12, –$18.59, and –$14.97.

A comparable analysis for cover crops followed by soybeans yields similar qualitative and quantitative results (Table 6). The average changes in net returns due to cover crop use followed by soybeans, excluding savings in livestock feed due to grazing or forage, for operators with up to 3 years of experience, with 4 to 9 years of experience, and with 10 or more years of experience amounted, respectively, to –$24.36, –$11.70, and –$21.04. An important difference between Tables 5 and 6 from the agronomic (although not the economic) standpoint is that while the average corn yield drag from cover crops declined with experience, the opposite trend was observed in the average soybean yield drag from cover crops. The average change in soybean yields due to cover crop use was 0.43 bushels for farmers with up to 3 years of experience, 0.25 bushels for farmers with 4 to 9 years of experience, and -0.09 bushels for farmers with 10 or more years of experience.

Net Returns to Cereal Rye (Followed by Corn) by Tillage Practices

To examine the relationship between tillage practices and net returns to cover crop use, we developed partial budgets for cereal rye terminated with herbicides and followed by corn, across all planting methods, for (a) no-till, (b) reduced-till, and (c) conventional- or vertical-till operations (Table 7). The number of respondents using no-till practices is more than three times the number of respondents using reduced till, or conventional or vertical till.

While the three partial budgets have similar planting costs for cereal rye, they differ in the costs to terminate cereal rye. Those differences are driven by the extra labor hours required to terminate cereal rye with herbicides among farmers who apply a preplant burndown in all acres and the custom rate paid by farmers who hire custom sprayers to terminate the cereal rye. The average change in total costs in the no-till budget is similar

Table 5. Changes in Net Returns Due to Cover Crop Use Followed by Corn, for All Cover Crop Species, All Planting Methods, Terminated With Herbicides, by Farmer's Years of Experience Using Cover Crops

	(a)	(b)	(c)
	≤ 3 Years	4–9 Years	≥ 10 Years
Sources of Changes in Net Profits	Average $/Acre		
A. Changes in revenues			
1. Cost-share program	20.83	24.60	17.00
2. Value of change in following corn yield	–20.00	–0.41	2.00
3. Savings or extra revenue from grazing or harvesting cover crop for forage	80.00	35.00	28.50
Subtotal A. Changes in revenue	***80.83***	***59.19***	***47.50***
B. Changes in costs			
1. Cover crop planting			
a. Seeds	15.60	16.85	16.75
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	15.09	14.56	15.12
i. Custom work	18.50	13.92	13.33
ii. Noncustom	13.14	15.07	15.71
Subtotal B.1	*30.69*	*31.41*	*31.87*
2. Cover crop termination			
a. Extra expenses for farmers who applied herbicides to all acres (with and without cover crops)	5.00	10.79	1.55
i. Extra herbicide cost on top of regular weed control program	0.00	0.97	0.00
ii. Extra labor costs to apply herbicides on top of regular weed control program	0.00	7.65	1.18
iii. Other termination expenses	5.00	2.18	0.36
b. Extra expenses for farmers who did not apply herbicides before planting corn in acres without cover crops	15.17	17.42	8.25
i. Herbicide cost to terminate cover crops	8.00	9.27	4.00
ii. Herbicide application cost. Weighted average of custom and noncustom work.	7.17	8.15	4.25
1. Custom Work	14.00	17.00	0.00
2. Noncustom	4.89	5.20	4.25
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*7.26*	*12.41*	*2.10*
3. Changes in other costs˜			
a. Nitrogen costs	0.00	0.11	0.00
b. Change in cash rent due to cover crop use	0.00	–1.15	0.00
Subtotal B.3	*0.00*	*–1.05*	*0.00*
Subtotal B. Changes in costs	***37.95***	***42.78***	***33.97***
C. Net change in profits (C = A–B)	***42.88***	***16.41***	***13.53***
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–37.12***	***–18.59***	***–14.97***
Average change in corn yields following cover crops (bushels per acre)	***–5.0***	***–0.1***	***+0.5***
Number of respondents	***11***	***47***	***13***

˜ No respondent indicated changes in corn planting costs; N, P, K, manure, insecticide, fungicide, or soil testing costs; costs to repair soil erosion; or management time due to cover crop use.

Table 6. Changes in Net Returns Due to Cover Crop Use Followed by Soybeans, for All Cover Crop Species, All Planting Methods, Terminated With Herbicides, by Farmer's Years of Experience Using Cover Crops

	(a)	(b)	(c)
	≤ 3 Years	4–9 Years	≥ 10 Years
Sources of Changes in Net Profits	Average $/Acre		
A. Changes in revenues			
1. Cost-share program	15.00	22.63	15.75
2. Value of change in following soybean yield	4.29	2.50	–0.91
3. Savings or extra revenue from grazing or harvesting cover crop for forage	31.00	30.71	43.75
Subtotal A. Changes in revenue	***50.29***	***55.84***	***58.59***
B. Changes in costs			
1. Cover crop planting			
a. Seeds	14.17	18.00	16.33
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	15.99	18.04	16.22
i. Custom work	15.33	17.50	17.67
ii. Noncustom	17.95	19.84	15.86
Subtotal B.1	*30.16*	*36.04*	*32.55*
2. Cover crop termination			
a. Extra expenses for farmers that applied herbicides to all acres (with and without cover crops)	6.60	0.95	2.17
i. Extra herbicide cost on top of regular weed control program	0.00	0.41	0.25
ii. Extra labor costs to apply herbicides on top of regular weed control program	2.60	0.00	1.08
iii. Other termination expenses	4.00	0.55	0.83
b. Extra expenses for farmers who did not apply herbicides before planting soybean in acres without cover crops	24.96	14.00	10.32
i. Herbicide cost to terminate cover crops	19.33	8.00	6.00
ii. Herbicide application cost. Weighted average of custom and noncustom work.	5.63	6.00	4.32
1. Custom Work	8.00	0.00	0.00
2. Noncustom	3.25	6.00	4.32
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*13.48*	*2.04*	*3.33*
3. Changes in other costs˜			
a. Cash crop seed costs	0.00	–0.42	0.00
b. Change in cash rent due to cover crop use	0.00	–0.83	0.00
Subtotal B.3	*0.00*	*–1.26*	*0.00*
Subtotal B. Changes in costs	***43.64***	***36.83***	***35.88***
C. Net change in profits (C = A–B)	***6.64***	***19.01***	***22.71***
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–24.36***	***–11.70***	***–21.04***
Average change in soybean yields following cover crops (bushels per acre)	***+0.43***	***+0.25***	***–0.1***
Number of respondents	***8***	***26***	***14***

˜ No respondent indicated changes in corn planting costs; N, P, K, manure, insecticide, fungicide, or soil testing costs; costs to repair soil erosion; or management time due to cover crop use.

Table 7. Changes in Net Returns Due to Cereal Rye Use Followed by Corn, for All Planting Methods, Terminated With Herbicides, by Tillage System

	(a)	(b)	(c)
	No Till	Reduced Till	Conventional/ Vertical Till
Sources of Changes in Net Profits		Average $/Acre	
A. Changes in revenues			
1. Cost-share program	24.69	29.00	19.00
2. Value of change in following corn yield*	–14.17	4.57	–7.20
3. Savings or extra revenue from grazing or harvesting cover crop for forage	17.33	0.00	70.00
Subtotal A. Changes in revenue	***27.85***	***33.57***	***81.80***
B. Changes in costs			
1. Cover crop planting			
a. Seeds	17.03	18.17	15.88
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	15.12	12.94	14.04
i. Custom work	15.16	11.33	14.20
ii. Noncustom	15.08	14.15	13.93
Subtotal B.1	*32.15*	*31.11*	*29.92*
2. Cover crop termination			
a. Extra expenses for farmers who applied herbicides to all acres (with and without cover crops)	5.31	2.80	44.50
i. Extra herbicide cost on top of regular weed control program	0.69	0.00	2.50
ii. Extra labor costs to apply herbicides on top of regular weed control program	1.50	2.60	36.83
iii. Other termination expenses	3.12	0.20	5.17
b. Extra expenses for farmers who did not apply herbicides before planting corn in acres without cover crops	17.59	8.84	17.40
i. Herbicide cost to terminate cover crops	8.63	4.00	10.25
ii. Herbicide application cost. Weighted average of custom and noncustom work.	8.97	4.84	7.15
1. Custom work	30.00	0.00	10.50
2. Noncustom	4.76	4.84	5.81
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*8.20*	*3.81*	*33.66*
3. Changes in other costs~			
a. Nitrogen costs	0.00	0.00	0.45
b. Change in cash rent due to cover crop use	–1.11	0.00	–2.00
Subtotal B.3	*–1.11*	*0.00*	*–1.55*
Subtotal B. Changes in costs	***39.24***	***34.91***	***62.03***
C. Net change in profits (C = A–B)	***–11.38***	***–1.34***	***19.77***
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–28.72***	***–1.34***	***–50.23***
Average change in corn yields following cover crops (bushels per acre)	***–3.5***	***+1.1***	***–1.8***
Number of respondents	***35***	***7***	***11***

~ No respondent indicated changes in corn planting costs (including seeds); N, P, K, manure, insecticide, fungicide, or soil testing costs; costs to repair soil erosion; or management time due to cover crop use.

to the change in total costs in the reduced-till budget ($39.24 and $34.91, respectively) but is lower than in the conventional-till budget ($62.03). Furthermore, the average cost-share payments received by reduced-till farmers ($29.00) was higher than the corresponding payments received by no-till and conventional-till farmers ($24.69 and $19.00, respectively). Consequently, the net losses from cereal rye use (excluding savings in livestock feed from grazing or forage) were the smallest for reduced-till operations ($1.34), followed by no-till operations ($11.38) and conventional-till operations ($19.77).[10]

Net Returns to Cover Crops by Planting Method

The net returns to cover crops by planting methods, (a) drilling and (b) aerial seeding, were calculated across all cover crop species for no-till operations.[11] The average changes in costs due to cover crop use followed by corn were similar across planting methods: $40.55 for operations using drills and $42.59 for operations using aerial seeding (columns a and b, respectively, in Table 8). In both partial budgets, the average change in yields due to cover crop use was negative (around 3 bushels per acre), and nearly one-third of the operators received cost-share payments. The average net losses due to cover crop use followed by corn (excluding savings in livestock feed from grazing or forage) was slightly lower in operations that use drilling for planting cover crop seeds ($26.99) than in operations using aerial seeding ($34.53).

The average changes in costs due to cover crops in rotations followed by soybeans were similar across planting methods: $37.45 for operations using drills and $39.12 for operations using aerial seeding (columns c and d, respectively, in Table 8). Contrary to the changes in corn yields observed in columns a and b of Table 8, average changes in soybean yields are positive for both planting methods: 0.28 extra bushels in fields where cover crops were planted with drills and 0.50 extra bushels in fields that were aerial seeded. A larger proportion of farmers using aerial seeding received cost-share payments than among farmers using drills (65% vs. 38%), but the average payments were similar ($18.55 vs. $16.70). The average net losses due to cover crops in rotations followed by soybeans (excluding savings in livestock feed from grazing or forage) were slightly lower[12] in operations using aerial seeding ($15.58) than in operations using drills ($17.95). Note that the calculated net losses from cover crops followed by soybeans are on average smaller than the net losses from cover crops followed by corn.

Net Returns to Cover Crops by Termination Method

The net returns for alternative termination methods (herbicide application and tillage) for cover crops planted using drills and followed by corn were calculated across all cover crop species for operations using conventional- or vertical-till methods. In order to avoid large biases in the average measures caused by extreme values among few observations, the following discussion focuses only on median (instead of average) values. The median cost of planting cover crops using drill planters is slightly higher for operations that used herbicide termination than for operations that used tillage to terminate cover crops: $33.50 (Table 9) and $28.51 (Table 10), respectively. While the median extra cost to terminate cover crops was null for those farmers who applied the termination method to all their acreage (with and without cover crops) as part of spring preplanting soil conditioning, it amounted to $15.54 for farmers who only applied herbicides in the spring to their acres with cover crops (see Table 9). The resulting net losses due to cover crops (excluding savings in livestock feed from grazing or forage) were slightly lower for operations using tillage than for operations using herbicides as the selected termination method: $13.01 (see Table 10) and $20.61 (see Table 9).

CONCLUSION

The partial budgets presented in this essay serve as an assessment of the annual economic returns to adding cover crops into corn and soybean production systems in Iowa across different planting and termination methods, tillage practices, and levels of experience with cover crops. Net returns are consistently negative across all partial budgets for farmers who do not use cover crops for grazing livestock or forage. This finding might explain

Table 8. Changes in Net Returns Due to Cover Crop Use Followed by Corn Or Soybeans, for All Cover Crop Species, Terminated With Herbicides, in No-Till Systems, by Planting Method

	Followed by Corn		Followed by Soybeans	
	(a)	(b)	(c)	(d)
	Drilling	Aerial	Drilling	Aerial
Sources of Changes in Net Profits	Average $/Acre			
A. Changes in revenues				
1. Cost-share program	27.10	19.20	16.70	18.55
2. Value of change in following cash crop yield*	–13.55	–11.14	2.80	5.00
3. Savings or extra revenue from grazing or harvesting cover crop for forage	13.33	15.00	15.00	15.00
Subtotal A. Changes in revenue	***26.88***	***23.06***	***34.50***	***38.55***
B. Changes in costs				
1. Cover crop planting				
a. Seeds	18.03	19.31	16.67	18.06
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	15.94	16.00	17.82	18.18
i. Custom work	16.00	16.33	21.50	19.46
ii. Noncustom	15.90	15.01	17.21	14.00
Subtotal B.1	*33.97*	*35.31*	*34.49*	*36.24*
2. Cover crop termination				
a. Extra expenses for farmers who applied herbicides to all acres (with and without cover crops)	4.90	5.45	2.43	1.53
i. Extra herbicide cost on top of regular weed control program	0.79	0.00	0.00	0.00
ii. Extra labor costs to apply herbicides on top of regular weed control program	0.90	2.36	1.13	0.87
iii. Other termination expenses	3.21	3.09	1.30	0.67
b. Extra expenses for farmers who did not apply herbicides before planting corn in acres without cover crops	20.54	13.97	13.99	12.99
i. Herbicide cost to terminate cover crops	11.25	9.67	9.33	10.00
ii. Herbicide application cost. Weighted average of custom and noncustom work.	9.29	4.31	4.66	2.99
1. Custom Work	18.00	0.00	8.00	0.00
2. Noncustom	4.93	4.31	2.99	2.99
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*8.28*	*7.28*	*3.77*	*2.88*
3. Changes in other costs˜				
a. Nitrogen costs	–0.54	0.00	0.00	0.00
b. Costs to repair soil erosion	–0.11	0.00	–0.04	0.00
c. Change in cash rent due to cover crop use	–1.05	0.00	–0.77	0.00
Subtotal B.3	*–1.70*	*0.00*	*–0.81*	*0.00*
Subtotal B. Changes in costs	***40.55***	***42.59***	***37.45***	***39.12***
C. Net change in profits (C = A–B)	***–13.66***	***–19.53***	***–2.95***	***–0.58***
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–26.99***	***–34.53***	***–17.95***	***–15.58***
***Average change in corn or soybean yields following cover crops (bushels per acre)**	***–3.4***	***–2.8***	***+0.3***	***+0.5***
Number of respondents	***37***	***15***	***26***	***17***

˜ No respondent indicated changes in cash crop planting costs (including seeds); P, K, manure, insecticide, fungicide, or soil testing costs; or management time due to cover crop use.

Table 9. Changes in Net Returns Due to Cover Crop Use Followed by Corn, for All Cover Crop Species, Planted With Drills in Conventional or Vertical Tillage Systems, Herbicide Termination Method

Sources of Changes in Net Profits	Mean	Median	Range	#Obs.
		$/Acre		
A. Changes in revenues				
1. Cost-share program	16.75	16.00	[7; 28]	4
2. Value of change in following corn yield*	–8.00	0.00	[–40; 0]	5
3. Savings or extra revenue from grazing or harvesting cover crop for forage	80.00	80.00	[80; 80]	1
Subtotal A. Changes in revenue	***88.75***	***96.00***		
B. Changes in costs				
1. Cover crop planting				
a. Seeds	17.40	19.00	[10; 21]	5
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	14.50	14.50		
i. Custom work	14.33	15.00	[13; 15]	3
ii. Noncustom	14.57	14.28	[9.79; 19.38]	7
Subtotal B.1	*31.90*	*33.50*		
2. Cover crop termination				
a. Extra expenses for farmers that applied herbicides to all acres (with and without cover crops)	13.25	0.00		4
i. Extra herbicide cost on top of regular weed control program	0.00	0.00	[0; 0]	4
ii. Extra labor costs to apply herbicides on top of regular weed control program^	3.25	0.00	[0; 13]	4
iii. Other termination expenses	10.00	0.00	[0; 20]	4
b. Extra expenses for farmers who did not apply herbicides before planting corn in acres without cover crops	15.26	15.54		1
i. Herbicide cost to terminate cover crops	8.00	8.00	[8; 8]	1
ii. Herbicide application cost. Weighted average of custom and noncustom work.	7.26	7.54	[6.72; 7.54]	
1. Custom work	14.00	14.00	[14; 14]	1
2. Noncustom	5.02	5.38	[4.29; 5.38]	3
Subtotal B.2 (weighted average of B.2.a and B.2.b)	*13.65*	*3.11*		
3. Changes in other costs~				
Subtotal B.3	*0.00*	*0.00*	[0; 0]	8
Subtotal B. Changes in costs	***45.55***	***36.61***		
C. Net change in profits (C = A – B)	***43.20***	***59.39***		
C.1. Net change in profits excluding grazing/forage (C.1 = C – A.3)	***–36.80***	***–20.61***		

* Reported changes in corn yields following cover crops due to cover crop use ranged from –10 to 0 bushels per acre, with an average loss of 2.00 bushels. The median farmer reported no change in corn yields.

^ Reported changes in labor hours per acre to terminate cover crops with herbicides ranged from 0 to 1 hours and averaged 0.25 hours. The median farmer reported no extra labor to terminate cover crops.

~ No respondent indicated changes in cash crop planting costs (including seeds); N, P, K, manure, insecticide, fungicide, or soil testing costs; costs to repair soil erosion; or management time or cash rent paid due to cover crop use.

Table 10. Changes in Net Returns Due to Cover Crop Use Followed by Corn, for All Cover Crop Species, Terminated With Herbicides, in Conventional or Vertical Tillage Systems, Tillage Termination Method

Sources of Changes in Net Profits	Mean	Median	Range	#Obs.
		$/Acre		
A. Changes in revenues				
1. Cost-share program	15.50	15.50	[11; 20]	2
2. Value of change in following corn yield*	9.00	0.00	[0; 52]	8
3. Savings or extra revenue from grazing or harvesting cover crop for forage	41.00	20.00	[15; 88]	3
Subtotal A. Changes in revenue	***65.50***	***35.50***		
B. Changes in costs				
1. Cover crop planting				
a. Seeds	20.20	16.50	[5; 45]	10
b. Planting (excluding seeds). Weighted average of custom and noncustom work.	13.54	12.01		
i. Custom work	27.00	27.00	[27; 27]	1
ii. Noncustom	12.04	10.34	[7.59; 18.61]	9
Subtotal B.1	*33.74*	*28.51*		
2. Cover crop termination				
a. Extra expenses for farmers who used conventional till in all acres (with and without cover crops)	4.90	0.00		10
i. Extra labor costs to till cover crop acres on top of regular costs to till no cover crop acres^	3.90	0.00	[0; 13]	10
ii. Other termination expenses	1.00	0.00	[0; 5]	10
Subtotal B.2	*4.90*	*0.00*		
3. Changes in other costs˜				
a. Opportunity cost of management time˜	0.30	0.00	[0; 30]	10
Subtotal B.3	*0.30*	*0.00*		
Subtotal B. Changes in costs	***38.34***	***28.51***		
C. Net Change in Profits (C = A–B)	***26.56***	***6.99***		
C.1. Net Change in Profits excluding grazing/forage (C.1 = C – A.3)	***–14.44***	***–13.01***		

* Reported changes in corn yields following cover crops due to cover crop use ranged from –10 to 0 bushels per acre, with an average loss of 2.00 bushels. The median farmer reported no change in corn yields.

^ Reported changes in labor hours per acre to terminate cover crops with herbicides ranged from 0 to 1 hours and averaged 0.25 hours. The median farmer reported no extra labor to terminate cover crops.

˜ No respondent indicated changes in cash crop planting costs (including seeds); N, P, K, manure, insecticide, fungicide, or soil testing costs; costs to repair soil erosion; or management time or cash rent paid due to cover crop use.

the low rate of adoption of cover crops across the state of Iowa, despite the variety of cost-share programs available to promote the practice.

Farmers who are able to use cover crops for grazing livestock or forage typically derive positive net returns for cover crops if they also receive cost-share payments. When cost-share payments are excluded from the calculations, average net returns for all groups of farmers (including those who benefit from the cover crop–livestock interaction) become negative. Therefore, while cost-share payments are typically insufficient to cover all private costs associated with cover crop use, they are a critical incentive for supporting this practice.

This study suffers from several limitations related to the self-selection bias of survey respondents and the potential unrepresentativeness of the sample. However, the study provides a variety

of partial budgets based on field data (instead of experimental plots) from farmers who manage row crop production on acres with cover crops and on acres with no cover crops that can be used as benchmarks for current and potential cover croppers as well as ground-truth references for agricultural and conservation policy design. The results of the present study (particularly those comparing net returns across different levels of experience with cover crops), in conjunction with a lack of market valuations for actual soil health (rather than fixed soil quality indexes such as the Corn Suitability Rating 2 [Burras et al., 2015]), suggest that the necessary conditions to expand the practice according to the Iowa Nutrient Reduction Strategy (2014) are currently missing. Although incipient initiatives are discussing the path toward voluntary markets to monetize soil health (Noble Research Institute, 2018), market valuations for actual soil health might take several years or even decades to develop at a large scale. Potential measures to improve the economic viability of cover crops without increasing government transfers to cover croppers include (1) developing a more competitive market for cover crop seeds (offering at low cost a high-quality seed adapted to local conditions), (2) promoting the use of cover crops for livestock grazing or forage, and (3) developing and promoting location-specific guidelines to facilitate the decision-making process for farmers, seed companies, and implement dealers, particularly to minimize the yield drag on corn and soybeans while containing planting and termination costs. An obvious but likely unsustainable alternative (due to federal and state budget constraints) to reduce the net losses derived from cover crop use is to increase the flow of public monies to adopters of the practice through cost-share payments, subsidized seed bags, discounted crop insurance premiums, tax credits, or similar incentives.

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NOTES

1. The Iowa Nutrient Reduction Strategy (2014) lists cover crops as one of the practices with the greatest potential for nitrate-N reduction. Kaspar & Singer (2011), Chatterjee (2013), and Miguez (2016) also highlight the soil health effects and environmental benefits associated with cover crops.

2. Financial assistance comes from federal programs including the Environmental Quality Incentives Program, the Conservation Stewardship Program, and the Regional Conservation Partnership Program as well as programs from the Iowa Department of Agriculture and Land Stewardship through the Iowa Water Quality Initiative, state cost-share, and local watershed projects.

3. See footnote 2 for a list of programs providing financial assistant to cover crop users.

4. We believe that the high number of respondents with no experience with cover crops (35% of all respondents) is due to the dynamics of the rental cropland market and to a lesser extent the generational change of operators in Iowa.

5. Nearly two in five respondents hired custom planting work for their cover crop (see Table 1), and most of the custom-hired planting consisted of aerial seeding (55%), followed by drilling (25%) and broadcast seeding (16%).

6. Fifty-one percent of the respondents who planted corn in 2016 following cover crops had also planted corn in 2015.

7. Seventeen percent of the respondents who planted soybeans in 2016 following cover crops had also planted soybeans in 2015.

8. Similar conclusions apply when comparing the partial budgets for cover crops followed by corn (soybeans) calculated across farmers who used the cover crop biomass for livestock grazing or forage against the partial budgets for cover crops followed by corn (soybeans) calculated across farmers who did not use the cover crop biomass for livestock grazing or forage: \$18.15 versus –\$29.15 (\$20.74 versus -\$21.65).

9. Note that less than half of the farms in Tables 3 and 4 received cost-share payments.

10. The median (which is less affected by extreme values than the average) change in total costs in the no-till budget is similar to the change in total costs in the reduced-till budget (\$34.83 and \$33.85, respectively) but lower than in the conventional-till budget (\$46.26). Furthermore, the median cost-share payments received by reduced-till farmers (\$27.00) was higher than

the corresponding payments received by no-till and conventional-till farmers ($20.00 and $17.50, respectively). Consequently, the median net losses from cereal rye use (excluding savings in livestock feed from grazing or forage) were the smallest for reduced-till operations ($6.85), followed by no-till operations ($14.83) and conventional-till operations ($28.76).

11. The partial budgets for other planting methods are not reported because the number of observations was too small (five or fewer observations).

12. The conclusion is the opposite if median instead of average net losses are used in the comparison, but the medians are within $1.50 per acre of each other.

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