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# Cover crops use in Midwestern US agriculture: perceived benefits and net returns

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## Abstract

Despite being generally accepted as a promising conservation practice to reduce nitrate pollution and promote soil sustainability, cover crop adoption in Midwestern US agriculture is low. Based on focus groups, surveys and partial budgets, we calculated the annual net returns to cover crop use for farmers in Illinois, Iowa and Minnesota; and elicited farmers' perceptions about the pros and cons of incorporating cover crops to their row cropping systems. The novelty of our methodology resides in comparing each farmer's practices in the portion of their cropping system with cover crops (typically small), against their practices in the other portion of their cropping system without cover crops. The resulting comparisons, accounting for farmer heterogeneity, are more robust than the typical effects calculated by comparing indicators across cover crop users and unrelated non-adopters. Our results highlight the complicated nature of integrating cover crops into the crop production system and show that cover crops affect whole farm profitability through several channels besides establishment and termination costs. Despite farmers' positive perceptions about cover crops and the availability of cost-share programs, calculated annual net returns to cover crops use were negative for most participants.

## Introduction

Row crop farming in the Midwest has been increasingly singled out as a major non-point source of nitrate pollution in waterways, putting pressure on farmers to adopt conservation practices. One of the promising conservation practices is the use of cover crops, which has the potential to promote many aspects of soil and water sustainability (Kaspar and Singer, 2011; Chatterjee, 2013). For instance, preliminary results from simulations based on a long-term cover crop study in Iowa suggest that nitrate concentration in tile drainage can be reduced by 54% when a winter rye cover crop is added to corn–soybean acres (Miguez, 2016). Moreover, the Iowa Nutrient Reduction Strategy (2014) lists cover crops as one of the practices with the greatest potential for nitrate-N reduction. However, despite the considerable benefits that can be accrued by the cropping systems, adoption of cover crops is very low in the Midwest. The Natural Resource Conservation Service (2012) estimated that out of a possible 30 million acres of farmland in Iowa, only 100,000 acres were planted to cover crops in 2012. The Iowa Farm and Rural Life Poll (Arbuckle, 2015) reports that in 10 yr time, only 35% of farmers surveyed had increased their use of cover crops.

It has long been recognized that lack of familiarity with novel approaches in agriculture can inhibit adoption of conservation practices (Nassauer et al., 2011). Across four surveys (Watts and Myers, 2013, 2014, 2015, 2016), farmers reported the greatest challenges to using cover crops were establishment, time or labor required and increased management, and species selection. Farmers' perceptions that cover crops are costly was also found to be a major barrier to their adoption: 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'. During the 2014 National Conference on Cover Crops and Soil Health (Sustainable Agriculture Research and Education, 2014), participants highlighted the need for economic analyses to document short- and long-term impacts of cover crops. Roesch-McNally et al. (2017) found that despite having successfully planted cover crops, farmers tended to believe that greater economic incentives would be needed to spur more widespread adoption of the practice. The Natural Resource Conservation Service (2017) estimated that Iowa farmers planted more than 353,000 acres of cover crops with financial assistance from state and federal conservation programs in the fall of 2016—nearly 18% more than in the previous year.

Science-based information on the potential return on investment at the farm-level associated with the use of cover crops by Midwest farmers is very limited. A handful of papers

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evaluated the economic impact of cover crops on different cash crops, including Reddy (2001) focusing on soybeans in Mississippi; Mahama *et al.* (2016) focusing on corn in Kansas; and Roberts *et al.* (1998) focusing on no-till corn in Tennessee. However, those studies were based on field experiments set up to evaluate agronomic factors, and the resulting estimates of economic returns might not apply to real farms where management practices do not follow an experimental design. Roberts and Swinton (1996) used actual data from 15 farms growing corn in Michigan in 1994 to explore the relationship between operating costs and crop diversity, and they concluded that cover crops reduce non-point source pollution without significantly reducing net returns. Snapp *et al.* (2005) provided a summary of the potential benefits and costs from cover crops, both external and internal to the farm, and reported qualitative findings from the focus group discussions with eight Michigan potato farmers. Nevertheless, the focus group discussions were oriented toward farmers' perceptions rather than toward actual changes brought to the system by integrating cover crops. Roesch-McNally *et al.* (2017) also provided qualitative analysis of the focus group discussions with 29 Iowa row crop farmers, but the focus of the discussions were barriers to adoption of cover crops and approaches to overcome them, and no information on the actual differences in profits between the cropping systems was provided.

There is a gap in the literature on the actual changes in economic costs and revenues faced by farmers who choose to use cover crops in their corn–soybean rotations in the Midwest, and how they interact with farmers' perceptions about cover crops. This paper aims at developing appropriate economic evaluation instruments to bridge that gap, by (a) summarizing three focus group discussions with 16 experienced farmers who had planted cover crops for at least 3 yr; and (b) assessing the changes in farm profits induced by cover crops, based on a survey instrument developed specifically to encompass all changes in management practices discussed by the focus groups. Instead of focusing on the barriers to cover crop adoption, the present paper contributes to the existing literature by developing a set of tools that can be systematically implemented to identify the economic incentives faced by farmers when deciding whether to use cover crops. A pilot assessment among focus group participants indicated that despite evidence that cover crops reduced farm profitability in 2014/15 for most farmers, they continue to use cover crops for their perceived long-term benefits.

### Focus group

Focus groups are a form of group interview that is particularly useful for exploring people's knowledge and experiences (Kitzinger, 1995). In particular, we were interested in learning about the changes observed by farmers in their crop rotation systems since they first started using cover crops; and whether the motivations to use cover crops for the first time differed from the motivations to use cover crops in successive years.

To cover a wide range of different management practices and soil and weather conditions, Practical Farmers of Iowa recruited 16 farmers from Iowa, Minnesota and Illinois based on their years of experience with cover crops, species used, crop rotations used, interest in better understanding cover crops return on investment and availability. The focus group discussions were held in Ames (Iowa), Urbana (Illinois) and Albert Lea (Minnesota) during December 2015.

Following Morgan *et al.* (1998), we used the same procedures in all three discussions. A research team member who has extensive knowledge about cover crops and interacts with farmers on a regular basis moderated the discussions. We started with a 10-min presentation about the project and then opened a 2-h discussion revolving around ten structured questions. The first two questions asked the participants to introduce themselves and to describe their farms (i.e., location, soil types, rotations), and indicate when was the first time they planted cover crops (Appendices 1 and 2). The next two questions asked about what prompted the use of cover crops for the first time and what motivated the continued use of cover crops. After that, the moderator asked the participants to reflect on the differences in practices between rotations with and without cover crops for 2 min and to write down their thoughts before taking turns to share them with the group (Appendix 3). The same procedures were followed to discuss the differences in revenues and costs for rotations with and without cover crops.

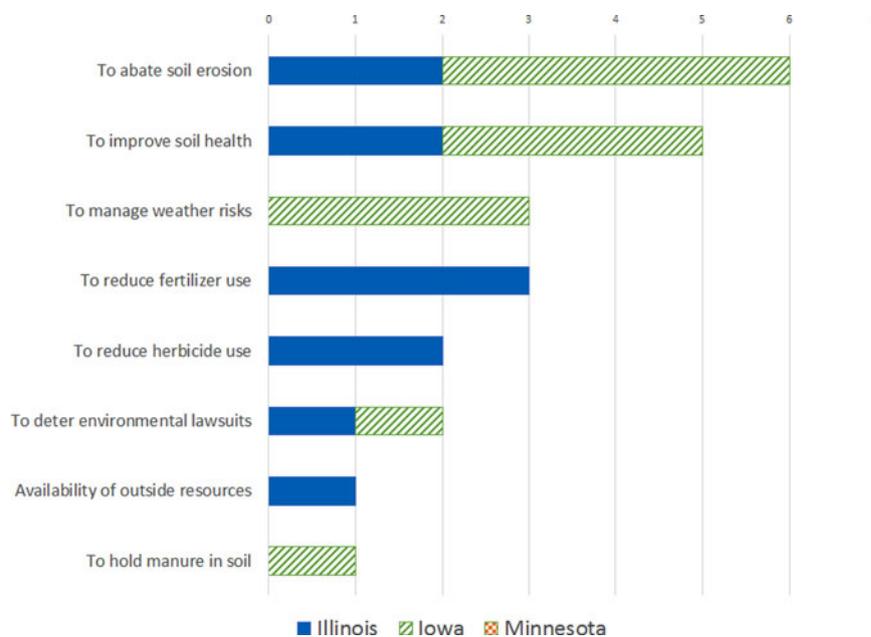
The discussions were recorded with farmers' written consent and later transcribed by a professional transcriber. A word cloud of all the transcribed material was created (Fig. 1). During the discussions, another team member annotated the main points on table top pads, and the main points were reviewed and summarized at the end of the meeting.

### Reasons for using cover crops

Most farmers first started using cover crops because of their potential benefits, such as soil health improvement and soil erosion abatement, and due to the availability of outside resources, e.g., education events, conferences and cost-share programs (Fig. 2). Two farmers also mentioned the family tradition of 'leaving the farm better than the way you found it'. Farmers had expectations that cover crops would lead to fertilizer savings from nutrient recycling and herbicide savings from weed control. One Minnesota farmer, who faced increasing competition from neighboring farmers attempting to outbid him for the farmland he had been leasing for several years, was the first one in the area to use cover crops on rented land as a way to differentiate himself from his neighbors and deter competition based solely on cash rents. One farmer from Minnesota mentioned improvement of water quality as one of the reasons.

The most common reason for continued cover crop use was the perceived reduction in soil erosion (Fig. 3). Six out of the eight farmers who had planted cover crops for more than 7 yr stated having seen considerably less soil erosion over the years, especially during excessive rainfall. Farmers also emphasized soil health improvement as an important factor: higher organic matter leading to the higher water holding capacity, increased biodiversity on the field and better soil quality in general. These improvements have the potential of translating into higher cash crop yields in the future. One farmer in Iowa described cover cropping as a risk management tool to protect their main asset, land, from extreme weather events. Another farmer from Illinois perceived cover crops as a legal risk management tool, in the sense that a history of documented conservation practices may considerably reduce the risk of being involved in an environmental lawsuit. The discussion took place while the lawsuit filed by Des Moines Water Works against ten Iowa drainage districts was open (Center for Agricultural Law and Taxation, 2017). A farmer from Iowa also expressed concerns over environmental lawsuits, but citing the algae bloom in Lake Erie, Ohio: 'I do not understand





**Fig. 3.** Count of farmers in focus groups citing alternative motivations to continue using cover crops (by state).

### Changes in crop management practices

Incorporating a new plant species into the rotation system entails new decisions. First, the choice of cover crop species, the approaches for planting and termination depend on the existing rotations, field conditions, weather and costs. Farmers across the three states switched to earlier varieties of soybeans or shorter season corn in order to plant cover crops earlier, and some moved the soybean planting date to an earlier date to accommodate an earlier harvest and therefore an earlier planting date for cover crops.

Farmers from Iowa reported experimenting with different varieties of cereal rye before selecting one with higher growth potential during the winter and a higher cost per bag than the typical bag of cereal rye available in the market. Farmers from Illinois described switching varieties of annual ryegrass after experiencing a failure to winter kill one variety, and the challenge to plant the following cash crop into growing ryegrass in a wet spring. Illinois farmers reported having tried more species and mixes than farmers from the other two states, probably due to the slightly warmer fall and winter temperatures in their area. Farmers in Minnesota have a shorter planting window, and they generally aerial seed cover crops into soybeans and cornstalks. When asked whether they would plant cover crops on all their hectares, a farmer said ‘...if the opportunity presents itself. It’s always weather’.

Cover crop adoption also heightened competition for resources such as farm labor and custom-hired services. For example, some farmers custom hire the planting and harvesting of the cash crop so that they can focus on planting and terminating the cover crops themselves. Four out of five farmers from Minnesota mentioned the difficulty of hiring aerial seeding in the early fall, especially when the demand for insecticide application was high; and, as a result, some of them had been moving cover crop planting a few days earlier every year.

Several farmers reported experiencing changes in costs related to cover crop use (Fig. 4). Changes in cash crop seed expenses were associated with changes in planting populations: one farmer in Iowa decreased the cash crop seeding rate with the expectation that the extra nutrients made available through cover cropping

would more than offset the negative effect of a lower seeding rate on cash crop yields; another farmer in Iowa increased the cash crop seeding rate because of the potential for slow soil warming in the presence of substantial biomass; and another farmer in Minnesota increased the seeding rate to compensate for a relatively late planting time.

One Iowa farmer had to buy new attachments for the soybean planter because of cover crop residue; other farmers bought tractors or drills for cover crop planting.

Some farmers experienced lower weed pressure and were able to lower their herbicide use. Conversely, one farmer increased the spraying rate and added an extra pass upon hearing rumors about voluntary cereal rye growing after termination.

One Iowa and two Minnesota farmers experienced an outbreak of armyworms in their fields, resulting in higher demand for scouting and insecticide use.

Various changes in fertilizer use, in terms of application time, method and amount, were reported. Changes in fertilizer use had different effects on costs across farmers. For example, three farmers from Minnesota lowered fertilizer costs because of the nitrogen credit, while some Iowa farmers applied extra nitrogen for corn at planting because they believed nitrogen would be tied up in the cover crop residue or increased the amount of phosphorous and potassium. Some farmers moved the anhydrous ammonia application from fall to spring; others applied less in the spring, holding the total amount unchanged.

A major added cost to the operation stemmed from the opportunity cost of time associated with extra management of the cropping system. Farmers reportedly needed to pay constant attention to the cover crops to prevent unexpected situations, or pay more attention to weather around planting and termination times.

Other reported changes in costs were less straightforward. A few farmers started to review their nitrogen programs and conduct soil testing to gather more information about nitrogen usage because of the potential of cover crops to sequester nitrogen. One farmer said: ‘it’s not a direct result of the cover crops but ... it was the cover crops that instigated the investigation of the soil health and the soil mechanisms.’ Some farmers extended

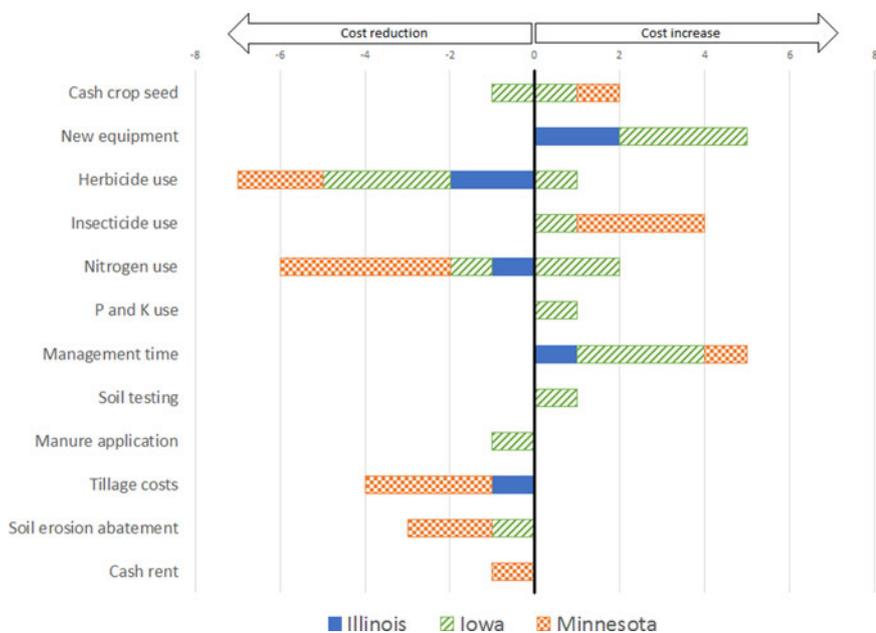


Fig. 4. Direct and indirect effects of cover crops on costs observed by farmers in focus groups since first use of cover crops (count by category and state).

practices that they found to be more efficient into hectares without cover crops as an ‘adaptation to cover crops’. For example, based on his investigation into soil health that started with cover crops, one farmer stopped using hog manure and started using soil samples to determine nutrient needs later delivered through side-dressing applications. These findings suggest that cover crops are associated with more research and experimentation toward integrated management and soil health improvement.

Cover crops also had implications for the tillage system. Four farmers from Minnesota and Illinois stated that they switched from conventional to no-till farming when they adopted cover crops, resulting in considerable savings in cost. Farmers agreed that the adoption of cover crops and the move toward no-till were both parts of the same effort to conserve soil: ‘It could be because of the cover crop. Or it could be that no-till and cover

crops go together.’ All participants from Iowa were long-time no-till farmers before starting to use cover crops. The improvement in soil condition led to other cost savings: three farmers eliminated the need to repair soil erosion, while the farmer from Minnesota that faced a competitive farmland rental market successfully used cover crops to negotiate an extension of their farm leasing contract maintaining the rental rate unchanged. Another farmer from Minnesota stated that they were able to renew their farmland leasing agreement because of promises to use cover crops to take better care of the soil, even though the benefit is hard to quantify.

Several farmers reported experiencing changes in revenues associated with cover crop use (Fig. 5). The only source of reduced revenue mentioned by farmers was yield losses in corn and soybeans. All losses occurred following the first or the second time

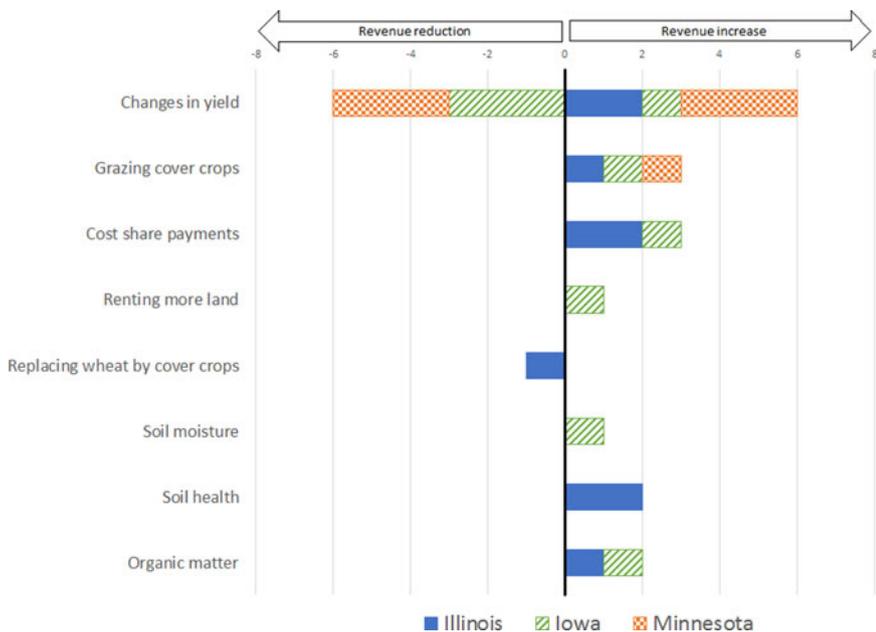


Fig. 5. Direct and indirect effects of cover crops on revenues observed by farmers in focus groups since first use of cover crops (count by category and state).

**Table 1.** Farmers' experience with cover crops and planted acres by summer 2015

Variable	Mean	Median	Standard deviation	Min	Max
Number of years of experience with cover crops	9.33	6	7	4	30
Total number of hectares planted to cover crops since starting using cover crops	994	749	747	324	2913
Hectares of cover crops planted in fall 2014	186	202	111	24	344

farmers planted cover crops when they were least knowledgeable about this practice. However, some farmers reported higher yields in corn and soybeans after several years of using cover crops, stemming from planting different hybrids or varieties, or from improved soil conditions. One farmer from Illinois believed that they had more consistent stands in the field where they had been planting cover crops for years.

Other sources of increased revenues were cost-share payments received by farmers and savings in livestock feed costs because of grazing or harvesting cover crops for forage.

A farmer in Illinois who grew wheat as a lower income cash crop to improve soil health reported obtaining similar results in terms of soil health by replacing wheat with cover crops (cereal rye and other grasses) in some acres. Despite losing revenue from the wheat enterprise, he expected an improvement in corn and soybean yields in the fields where cover crops were planted. Farmers in Iowa and Illinois reported seeing improvements in soil health, organic matter content and soil moisture stemming from cover crops use, and they believed that those effects would eventually translate into higher revenues.

Finally, a farmer in Iowa was able to expand his operation by outbidding other farmers competing for the same parcel of land after offering the landowner to plant cover crops on the rented ground as part of the leasing agreement.

## Follow-up survey

### Survey questionnaire

An online survey questionnaire to collect information on the changes in costs and revenues associated with the use of cover crops in row crop agriculture was developed based on the focus group discussions. We sent a follow-up online survey to all farmers in the focus groups in order to construct a partial budget for each of them for 2014/15 crop year, and to serve as a pilot survey for a larger project involving a regional survey. 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 et al., 1994). Partial budgets are designed to answer the question of how profits change when a modification is introduced to a baseline system of production. Since enterprise budgets are used to calculate the profitability of an enterprise, partial budgets capture, in essence, the differences between two enterprise budgets: one for a baseline enterprise (e.g., corn production), and one for another enterprise consisting of the baseline enterprise with some modification (e.g., corn production preceded by cover crops).

Instead of asking directly about changes in costs and revenues, the survey first asked farmers about revenues and expenses in their cropping system with cover crops, and second whether those values were different in their cropping system without cover crops. Finally, if a farmer indicated that a difference existed,

the survey then asked for the typical values in their cropping system without cover crops. We designed the display of questions to be conditional upon previous answers to minimize the number of questions presented to farmers.

The first section of the survey collected basic information, such as a number of years of experience with cover crops, total hectares of cover crops planted since starting using cover crops, and whether cover crops were used for grazing or as a forage. The survey instrument then asked which cover crop mix was most extensively planted in the fall of 2014 and the number of hectares planted (as opposed to farmers' experience with all cover crops discussed in the focus groups). The next section focused on the added costs associated with seed and planting of the cover crop chosen, followed by a question concerning termination. The second part of the survey asked which cash crop was most extensively planted in the spring of 2015 following the cover crop, the number of hectares planted, and the observed differences in yield and other sources of revenues, compared with the typical values without cover crops. The questionnaire then focused on sources of changes in costs, such as planting, fertilizer use, herbicide use and tillage. The last section asked about the cash crop harvested in 2014, preceding the reported cover crop mix.

Some of the questions regarding cash revenues and costs in the survey asked for dollar values, including those about cost-share payment received, seed costs, fertilizer costs, herbicide costs or custom-hired work. For non-cash costs, such as the costs of own machinery, the survey asked about the type of machinery used and the number of field passes. The associated costs were derived from a partial budget tool developed specifically for cover crop budgeting by the Natural Resource Conservation Service (Cartwright and Kirwan, 2014). The partial budget tool

**Table 2.** Count of survey respondents by cover crop species, following cash crop and termination method by state

		IA	MN	IL	Total
Cover crop species	Cereal rye	4	3	4	11
	Other <sup>a</sup>	2	2		4
Following cash crop	Corn	1	5		6
	Soybean			4	8
	Half corn/half soybean	1			1
Termination method	Herbicide	6	3	4	13
	Tillage		1		1
	Winterkill		1		1

<sup>a</sup>Other included annual ryegrass; cereal rye, crimson clover and radish; and oats, radish and hairy vetch.

is an Excel® spreadsheet that asks the user to input information on farm management practices and calculates the net change in profit associated with the incorporation of cover crops into the user-defined cropping system. The partial budget tool includes costs for a list of machineries that served as the basis for our pilot survey.

Our pilot survey also asked for labor hours involved in the activity along with the machinery used. The opportunity cost of added management was calculated as the product of the number of additional management hours from cover crop use for the field under analysis and a US\$13.80 h<sup>-1</sup> wage rate, divided by the number of hectares managed. The wage rate used for management work is higher than the wage rate for non-management work (US\$12 h<sup>-1</sup>) used in Cartwright and Kirwan (2014) to reflect the higher opportunity cost of the former.

To calculate changes in revenue stemming from yield differences, 2015 marketing year average prices for corn [US

\$138.58 metric ton (mt)<sup>-1</sup>] and soybeans (US\$327.39 mt<sup>-1</sup>) from the National Agricultural Statistics Service (2017) were used.

### Survey results

After two rounds of reminders, 15 out of the 16 focus groups participants completed the survey. On average, respondents had 9 yr of experience with cover crops and had planted 994 hectare (ha) to cover crops over the years by summer 2015 (Table 1). The average number of acres planted to cover crops per respondent in fall 2014 was 186 ha, accounting for 19% of the average total area planted to cover crops over the years. This finding reflects the fact that participating farmers started using cover crops in small test plots, and, as they developed adjustments to their crop management practices, the area planted to cover crops tended to increase. Eleven farmers planted cereal rye and the rest planted

**Table 3.** Changes in revenues, costs and net returns for survey participants, in US\$ ha<sup>-1</sup>

Sources of changes in net profits	Mean	Median	Standard deviation	Range	Number of responses
	US\$ ha <sup>-1</sup>				
<b>(A) Changes in revenues</b>					
(1) Cost-share program	28.99	24.71	14.10	[0; 98.8]	15
(2) Value of change in following cash crop yield	22.14	0.00	18.34	[0; 156.6]	15
(3) Savings or extra revenue from grazing or harvesting cover crop for forage	1.65	0.00	2.58	[0; 24.7]	15
<b>Subtotal A. Changes in revenue</b>	<b>52.78</b>	<b>37.07</b>	<b>26.75</b>	<b>[0; 243.1]</b>	<b>15</b>
<b>(B) Changes in costs</b>					
(1) Cover crop planting					
(a) Seeds	50.41	44.48	9.52	[24.7; 108.7]	15
(b) Planting (excluding seeds)	50.08	49.42	5.10	[29.7; 77.1]	15
<i>Subtotal B.1</i>	<i>100.49</i>	<i>97.61</i>	<i>11.84</i>	<i>[66.7; 162.5]</i>	<i>15</i>
(2) Cover crop termination <sup>a</sup>					
(a) Extra expenses for farmers that applied herbicides to all acres (with and without cover crops)	1.57	0.00	5.70	[-24.7; 37.1]	11
(b) Extra expenses for farmers that did not apply herbicides before planting cash crop in acres without cover crops	38.36	38.36	2.38	[34.2; 42.5]	2
(c) Extra expenses for farmers that used winterkill or tillage to terminate cover crops	0.00	0.00	0.00	[0, 0]	2
<i>Subtotal B.2</i>	<i>6.27</i>	<i>0.00</i>	<i>7.17</i>	<i>[-24.7; 42.5]</i>	<i>15</i>
(3) Changes in other costs					
(a) Nitrogen costs	1.61	0.00	7.72	[-37.1; 61.3]	15
(b) Tillage costs	-0.74	0.00	2.35	[-20; 8.9]	15
(c) Costs to repair soil erosion	-2.72	0.00	3.23	[-30.9; 0]	15
(d) Opportunity cost of management time~	1.59	0.21	0.89	[0; 6.84]	15
<i>Subtotal B.3</i>	<i>-0.26</i>	<i>0.09</i>	<i>9.55</i>	<i>[-56.7; 61.3]</i>	<i>15</i>
<b>Subtotal B. Changes in costs</b>	<b>106.50</b>	<b>101.13</b>	<b>19.89</b>	<b>[17.4; 206.1]</b>	<b>15</b>
<b>(C) Net change in profits (C = A - B)</b>	<b>-53.72</b>	<b>-64.06</b>	<b>32.79</b>	<b>[-166.4; 163.3]</b>	<b>15</b>

<sup>a</sup>Most farmers applied herbicides to all their acres in spring and therefore incurred in little to no extra herbicide costs to terminate cover crops. One farmer relied on winterkill to terminate cover crops, so no extra termination cost was assigned to that farmer. Another farmer used tillage to terminate cover crops, but since this farmer used rotational tillage in all his hectares, the extra termination costs were null.

annual ryegrass or mixes including radish (Table 2). In 2015, two Iowa farmers and all Minnesota farmers planted corn following cover crops, while all Illinois farmers planted soybeans. During the focus group discussions, one farmer from Illinois mentioned that they had experienced yield losses in corn following annual ryegrass because the field was too muddy. Most farmers terminated their cover crops by herbicide applications, except for two Minnesota farmers who relied on tillage or winter kill.

We calculated the net change in profits associated with cover crops use for each respondent by manually entering the values from the online survey into the digital partial budget tool (Cartwright and Kirwan, 2014) (Table 3). The use of cover crops in 2014 entailed, on average, an economic loss of US \$53.72 ha<sup>-1</sup>. Calculated net changes in profits ranged from a reduction of US\$166.4 ha<sup>-1</sup> to an increase of US\$163.3, with a median net decrease in profits of US\$64.06 ha<sup>-1</sup>.

The main drivers of added costs were cover crop seed and planting expenses. The costs for cover crop termination were relatively low, on average. However, termination costs varied substantially across farms, depending on the termination method and the typical pre-plant spring management practices. Thirteen farmers used herbicides to terminate cover crops, but 11 of them typically apply a pre-plant burn down to all their fields irrespectively of the use of cover crops. Consequently, little to no additional herbicide costs were associated with cover crops for those 11 farmers. The other two farmers incurred termination costs ranging from US \$34.2 to 42.5 ha<sup>-1</sup>. The termination costs for farmers that relied on winter kill or used tillage to terminate cover crops were null. In the latter case, the farmer used rotational till on all his acres (with and without cover crops), and tillage was an expense that would have been incurred irrespectively of cover crops use.

Nitrogen use, herbicide use and tillage contribute to increased costs for some farms and reduced costs for some other farms (see

the range of values reported for those variables in Table 3), in line with the conclusions reached in the focus group discussions. However, the median changes for those variables were zero.

Cost-share program payments and yield increases generated average increases in revenues of US\$28.99 and 22.14 ha<sup>-1</sup>, respectively. Only one farmer reported extra revenue from grazing cover crops, at a rate of US\$24.7 ha<sup>-1</sup> in 2015. However, the median changes in revenues due to yield increase or grazing across survey respondents were zero. No farmer reported decreases in revenue in 2015 due to cover crops.

The net returns to cover crop use were positive only for one farmer in Iowa and two farmers in Minnesota (Fig. 5). They all reported yield increases and modest cover crop seed costs, two received cost-share payments and one of them is the only farmer who reported added revenues from grazing. Eleven out of 15 farmers reported increases in management hours, although the calculated extra costs per hectare (calculated as extra management hours per year multiplied by a wage rate of US\$13.8 h<sup>-1</sup>, and divided by the number of hectares planted to the following cash crop) were relatively low. Only three farmers reported saving costs from soil erosion repairs in 2015 due to cover crops use, with an average of US\$17.90 ha<sup>-1</sup>. Cost-share payments received by eight farmers averaged US\$54.40 ha<sup>-1</sup>. The four farmers with larger than average cover crop seed expenses (US \$50.41 ha<sup>-1</sup>) were the ones who experienced the largest reductions in profits per hectare due to cover crop use. However, no distinct cost patterns were observed across cover crop species or states due to the small sample size.

We attempted an analysis of net changes in profits for different configurations of costs and revenues (Table 4). Interestingly, the net changes in profits for three out of the four farms that experienced cash crop yield increases in 2015 due to cover crop use were positive, and the average increase in profits across the four farms

**Table 4.** Net change in profits for alternative costs and revenues configurations

Net change in profits (in parenthesis: reference to items in Table 3)	Mean	Median	Standard deviation	Range	Number of responses
(C) Net change in profits (C = A–B)	–53.72	–64.06	32.79	[–166.4; 163.3]	15
(C.1) Net change in profits excluding cost savings or extra revenue from grazing or harvesting cover crop for forage (C.1 = C–A.3)	–55.36	–64.06	30.93	[–166.4; 138.6]	15
(C.1.a) Net change in profits excluding cost savings or extra revenue from grazing or harvesting cover crop for forage, only for farms that experienced cash crop yield increases in 2015	35.20	15.03	29.30	[–27.8; 138.6]	4
(C.1.b) Net change in profits excluding cost savings or extra revenue from grazing or harvesting cover crop for forage, only for farms that experienced cash crop yield losses in 2015	–88.30	–83.35	18.68	[–166.4; –25.8]	11
(C.2) Net change in profits excluding changes in revenue from grazing/harvesting for forage and cost-share payment (C.2 = C.1 –A.1)	–84.36	–86.49	30.43	[–206.1; 76.8]	15
(C.3) Net change in profits excluding changes in revenue from grazing/harvesting for forage and cost-share payments for farmers that applied herbicides to all acres (C.3 = A–B.1–B.2.a–B.3)	–42.88	–47.16	33.28	[–163.7; 163.3]	11
(C.4) Net change in profits excluding changes in revenue from grazing/harvesting for forage and cost-share payments for farmers that terminated cover crops with herbicides but did not apply herbicides before planting the cash crop in acres without cover crops (C.4 = A–B.1–B.2.b–B.3)	–136.84	–136.84	16.91	[–166.4; –107.3]	2
(C.5) Net change in profits excluding changes in revenue from grazing and cost-share payments for farmers that terminated cover crops with tillage or winterkill (C.5 = A–B.1–B.2.c–B.3)	–30.19	–30.19	32.22	[–86.5; 26.1]	2

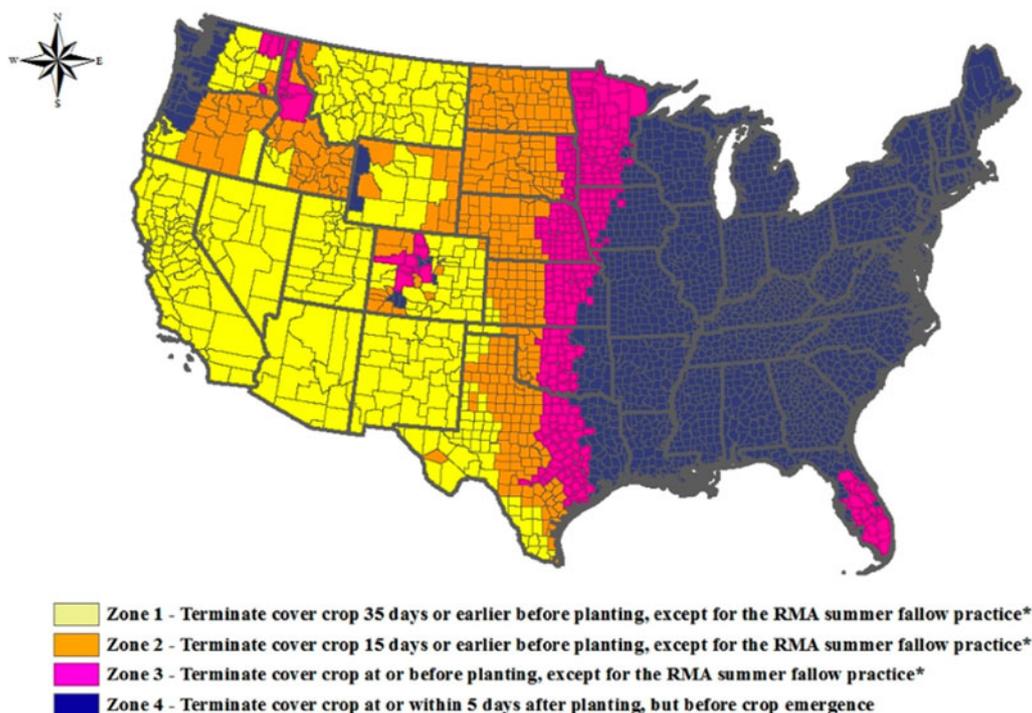


Fig. 6. Cover crop termination zones (Source: Natural Resource Conservation Service 2014).

amounted to US\$35.20 ha<sup>-1</sup>. No other configuration of changes in costs and revenues resulted in average increases in profits for the farmers in the sample.

## Discussion

The average change in net returns due to cover crop use in 2014 among the experienced farmers in the present study was negative, even after accounting for cost-share payments. Therefore, cost-share programs are likely to play a key role in incentivizing cover crop use among inexperienced farmers.

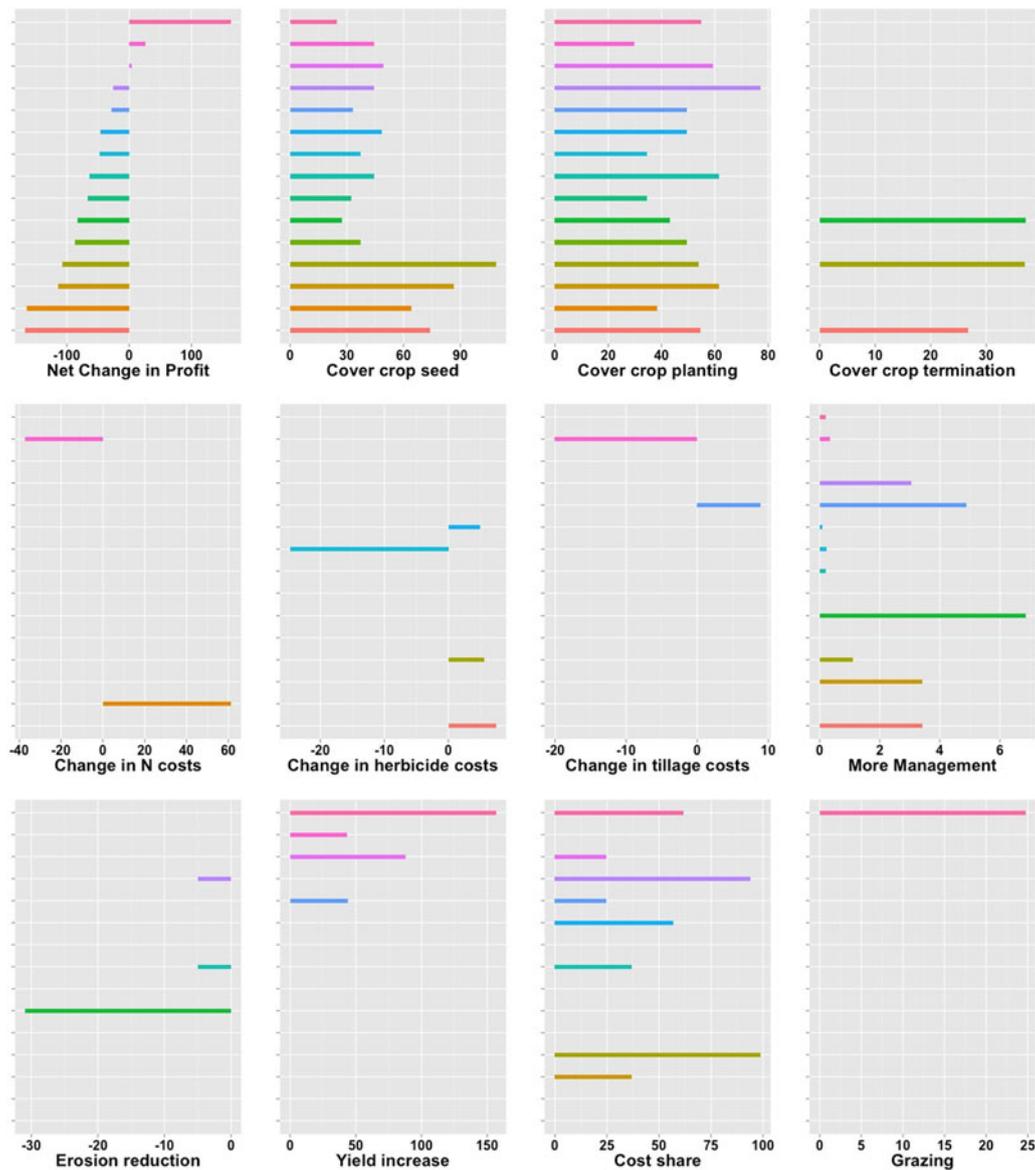
Throughout the three focus group discussions, farmers stressed the need for information, opportunities for trials and errors for their particular situation, and more management time to make cover crops successful. One focus group participant mentioned that some neighboring farmers had discontinued the use of cover crops because of added time management.

Cover crops brought numerous new management decisions, sometimes because of a limited time window to complete tasks due to weather or availability of resources. Farmers in different regions face different constraints. Crop insurance is one of those constraints. Figure 6 shows the cover crop termination zone defined by the Natural Resources Conservation Service (2017) guidelines. It defines the deadline for cover crop termination by locations of the farm. If farmers want to experiment interseeding cover crops into a standing cash crop before physiological maturity, they would need to discuss it with an insurance agent ahead of time, provide relevant production records and may have to bear additional risks. One farmer from the focus group recounted giving up on an experiment because of a concern for losing crop insurance.

Cover crops also entailed new risks. During the three focus groups, farmers shared their experiences with yield reductions in

cash crops due to various reasons: herbicide failure to control the cover crop, pest outbreaks or failure of cover crop to winterkill.

It is possible that these focus group participants were more interested in conservation and soil building than in their short-term economic returns to cover crops use. This might have influenced their valuation of perceived benefits stemming from cover crops use. For example, some farmers stated having seen major yield increases since adopting the practice, while some farmers found it hard to judge because fluctuations in yields could have been driven by a myriad of factors. However, a stronger consensus existed regarding the benefits of cover crops in reducing soil erosion and increasing soil organic matter. To these farmers, the use of cover crops was only one part of their efforts toward integrating management and soil health improvement. All participants mentioned the fact that they knew of no available method to quantify the benefits from cover crops, and stressed the need to quantify those gains in order to properly weigh the short-term costs and the long-term benefits, which is especially relevant in the context of the land tenure. Each farmer received a copy of their own partial budget results, as well as a set of graphs summarizing the anonymized partial budgets results for all survey respondents (Fig. 7). Only one farmer provided feedback on those results, and although they accepted that in any given year annual returns to cover crops can be negative, they felt that more research was needed to understand the long-term economic returns to cover crops: 'Your study so far has focused on the short-term agronomic benefits of cover crops as a standalone practice. Most of what we get in return from cover crop use is from growing soil under regenerative management and cannot be quantified separately as there is no way to determine if the plant residue we are converting to soil organic matter comes from the cash crops or cover crops. When selecting cover crop species to plant, balancing the carbon/ nitrogen ratio as close to 25/1 is a primary goal. As for the short-term agronomic benefits of using cover crops we've had



**Fig. 7.** Calculated changes in costs, revenues and profits from our partial budgets for each survey respondent, in US\$ ha<sup>-1</sup>.

about an equal number of wins and losses. We have a lot of knowledge in regards to regenerative management, but little of it is quantified. We have tried many times to get funding and grants to do the quantifying, but were always turned down.'

Although the results presented in this study might not be representative of all Midwest farmers due to the small sample size, they highlight the role of regional and crop production system specificities in the analysis of private and social benefits stemming from cover crops.

## Conclusions

This paper documents the management decisions involved in incorporating cover crops into row crop systems; identifies relevant challenges faced by cover crop adopters; and the strategies implemented to continue using cover crops, despite our evidence suggesting that cover crops reduce farm profitability for most farmers in the short run.

Our findings highlight some common elements affecting the decisions to adopt cover crops in Iowa, Illinois and Minnesota; but most importantly, they highlight that cover crop use might be associated with cost reductions in specific lines of the budget for farmers in one state and cost increases in the same line for farmers in another state. The corollary of this result is that general agronomic and economic recommendations for all types of cover crops in Midwestern row crop production systems should be avoided, and instead recommendations should be issued for a specific region and a specific cover crop mix.

**Supplementary material.** The supplementary material for this article can be found at <https://doi.org/10.1017/S1742170518000194>

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