Are cover crops being used in the US corn belt?

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Abstract: The benefits of using cover crops are well established, but adoption in agronomic farming systems is unknown. The objectives of this study were to quantify cover crop use and identify factors associated with their adoption. A mail survey was sent to 3,500 farmers in the US corn belt (Illinois, Indiana, Iowa, and Minnesota) to quantify farming practices and cover crop use. An estimated 18% of farmers have used cover crops, including 11% who planted cover crops sometime in the last five years, and 8% who planted cover crops in the fall of 2005. In the fall of 2005, farmers who used cover crops planted them on 6% of the land area for the average size farm. Logistic regression results indicated that crop diversity in a farm operation was the most consistent and important factor related to the use of cover crops. Corn belt farmers believe that cover crops are most effective at reducing soil erosion (96%) and increasing soil organic matter (74%). Approximately 56% of farmers indicated that they would plant cover crops if cost-sharing was available. The mean minimum payment required as an incentive to plant cover crops would be approximately \$56.81 ha^{-1} (\$23 ac^{-1}).

Key words: conservation practices—cover crops—US corn belt

The benefits of using cover crops are well established in the scientific literature, but adoption among end-users in agronomic farming systems is unknown. Cover crops are generally defined as plants that cover the soil and are primarily used to reduce soil erosion (Zhu et al. 1989; Kaspar et al. 2001) and nitrogen (N) leaching losses (Kladivko et al. 2004; Strock et al. 2004; Kaspar et al. 2007). Cover crop research has increased steadily since the 1970s to provide management tools to bridge the gap created by the loss of perennials and winter annual cash grains in crop rotations that were replaced by summer annuals. Cover crop use is greater in higher value farming systems, such as vegetable production. Young and Tucker (1999) reported that cover crops were used by 69% of respondents in their survey of vegetable growers in a six-county region of western New York. Mallory et al. (1998) reported that farmers participating in their study who grew short-season vegetables in rotation with corn (*Zea mays* L., n = 6) would use cover crops primarily to provide ground cover and secondarily on the profitability of using cover crops as a nitrogen source.

Limited regional information is available for quantifying cover crop use in agronomic farming systems. Drost et al. (1996) surveyed Utah producers and reported that 56% of respondents in their survey (n = 351) used cover crops. Cover crops were not defined, although 86% of respondents reported that they had long-term rotations in which alfalfa (*Medicago sativa* L.) was the dominant legume (93% of all legumes). The Maryland Department of Agriculture (MDA) conducted a cover crop mail survey of 1,600 randomly sampled Maryland farm operators. They reported that 60% of survey respondents had used cover crops in the previous 10 years (Tributary Strategy Implementation Team 1997). Six percent of respondents had participated in the MDA program for winter cover crops and more than 50% had planted cover crops without financial assistance. Snapp et al. (2005) hosted focus group discussions with eight Michigan potato (*Solanum* spp.) farmers to understand perceived problems and benefits associated with cover crop selection and management. They concluded that farmers understand the benefits of using cover crops but are also concerned about the risks, such as residue management and N dynamics, and that improved knowledge about cover crop management may increase adoption.

Adoption of cover crops in agronomic farming systems may improve natural resource conservation and maintain soil productivity. Furthermore, the role and benefits of cover crops may increase as shifts in acreages to crops with greater nitrogen demand such as corn occur in response to current and new markets. The use of crop residues as feedstocks for energy production may increase the need for soil cover to maintain soil productivity. Before cover crop use can increase, impediments to adoption must be defined and addressed. In spite of a wealth of scientific knowledge on cover crops, anecdotal observations indicate their use is low in farming systems dominated by summer annual crops. The objectives of this study were to quantify cover crop use in the US corn belt and identify factors associated with their adoption.

Materials and Methods

Survey Methods. A mail survey approach was used to collect data from farmers in four corn belt states (Illinois, Indiana, Iowa, and Minnesota) who were actively farming in 2006 (Larson et al. 2007). The sampling frame used to select the sample was a list of individuals, addresses, and occupation codes (using the standard industrial classification system) maintained by Survey Sampling International. For sampling purposes, farmers were defined to be any person whose occupation involves farming with wheat (*Triticum aestivum* L.), corn, soybean (*Glycine max* [L.] Merr.), cash grains, or who operates a general farm that primarily grows crops. Based on prior experience, we expected about 15% of the list using this definition to include "ineligible" farmer operators who did not belong to the target population (e.g., were not farming in 2006), and we expected approximately one third of operators who farmed in 2006 to respond to the mail survey. Because our goal was to obtain about 250 completed responses per state, a stratified random sample of 3,500 farmers was selected by sampling 875 farmers from each state.

The survey included questions about the respondent's farming operation, practices and

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government program participation, knowledge and attitudes about cover crops, and use of cover crops at any time in the past, in the prior 5 years, and in the fall of 2005. Cover crops were defined as plants growing between regular grain crop production periods. The first mailing was sent to respondents at the end of June 2006. A reminder postcard was sent to nonrespondents in mid-July, a second complete mailing of the survey was sent to non-respondents in late July, with responses received through mid-September.

A total of 1,096 completed and useable surveys were received, with 258 from Illinois, 253 from Indiana, 316 from Iowa and 269 from Minnesota. After adjusting for individuals who were not farming in 2006, the overall response rate was calculated to be 36.1%, with response rates in Illinois, Indiana, Iowa, and Minnesota of 33.9%, 33.6%, 42.1%, and 35.0%, respectively (using response rate method 4, American Association of Public Opinion Research 2006, p. 33). Sample weights were calculated for each completed response using standard ratio procedures (Lohr 1999) to adjust for the presence of individuals who did not farm in 2006 in the sampling list and for differential sampling and nonresponse rates across states.

Analysis Methods. To summarize the data, weighted estimates of means, percentages and the number of farmers with a specific characteristic in the study region or in a specific state were calculated using stratified sample estimators available in SAS version 9.1 (SAS Institute 2003) software. For estimation of standard errors, states were declared as strata. An approximate 95% confidence interval (CI) (also known as a margin of error) was calculated for each estimate. Differences in farm characteristics for farmers who have used cover crops at any time in the past and farmers who have never used cover crops were examined using an independent two-sample Z-test to test the null hypothesis that the mean of each characteristic is different for the two groups of farmers. The characteristics included the number of acres farmed, the number of crops farmed, whether or not only crops were grown on the farm, whether or not the farmer both planted crops and raised livestock, whether or not the farmer implemented conservation practices, and whether or not a farmer receiving incentives would actually adopt conservation practices without incentives.

To investigate factors that affect the use of cover crops for each state, the indicator of whether or not a producer had ever used cover crops was regressed on several variables using a logistic regression model. Covariates included the number of years the producer had farmed, whether or not the producer had formal education beyond high school, the proportion of operated land that was owned by the producer, the number of crops farmed, whether or not the producer participated in a conservation program, and whether or not the producer perceived advantages of cover crops including yield, soil, and soil water improvements. The latter two variables were constructed from a question where respondents stated whether each of several conditions were an advantage of using cover crops. The conditions included: reduce soil erosion, increase water infiltration, decrease runoff, increase soil organic matter, and reduce soil compaction. A soil advantage indicator variable was created by assigning a value of one if a respondent replied that cover crop advantages included increasing soil organic matter or reducing soil compaction; a value of zero was assigned if the respondent did not cite either of these outcomes. A second variable was created to indicate a soil water advantage by assigning a one if the respondent said yes to reducing soil erosion, increasing water infiltration or reducing run-off, and a zero if none of these advantages were perceived. Results indicated that water-related improvements were recognized by nearly all respondents as an advantage of using cover crops. Thus, this factor was not included in the regression because the lack of variation across respondents makes it impossible for this variable to discriminate between those who did and did not adopt cover crops.

Maximum likelihood estimates of regression parameters and their standard errors were calculated, and chi-square tests were used to test whether each regression parameter was significantly different from zero. Odds ratios were also estimated along with CIs for the ratios. An odds ratio expresses the likelihood of having ever used cover crops more under one condition than another (e.g., enrolled in a program vs. not enrolled) holding all other variables constant. If the CI for the odds ratio does not include one, then the ratio is considered significantly different from one, indicating that there is a difference in the likelihood of using cover crops for the two conditions. Estimates that are significantly greater than one (i.e., both CI endpoints are above 1) indicate that crop cover adoption is more likely under the first condition, while odds ratio estimates that are significantly less than one (i.e., both CI endpoints are under 1) indicate adoption is more likely under the second condition. For example, an odds ratio of 2.3 indicates that adoption of cover crops is 2.3 times more likely under the first condition. When an odds ratio is calculated for a variable such as number of crops grown, the likelihood of adoption for a farmer with x + 1 crops (e.g., 3) is compared with a farmer with x crops (e.g., 2).

The Hosmer-Lemeshow lack-of-fit test and residual plots were used to evaluate model fit and to detect outliers and influential points, respectively. Test results suggested a reasonable model fit and an absence of outliers and influential points for each of the four state regressions. Regression parameters were considered significant if p-values were less than 0.05. Although analogous logistic regression analyses were also attempted for indicators of the respondent planting cover crops sometime in the last five years or in the fall of 2005, the scarcity of adopters led to poor regression diagnostics for several regressions.

Results and Discussion

An estimated 18% (15.5%, 20.1%; 95% CI) of farmers in the US corn belt have used cover crops in their farming system in the past. Only 11% (9.4%, 13.2%) reported using a cover crop during the past five years and 8% (6.2%, 9.4%) planted a cover crop in the fall of 2005. Cover crop use in the past five years was markedly different by state with farmers using more cover crops in Indiana (15.9% [11.3%, 20.5%]) and Illinois (15.7% [11.2%, 20.2%]) than Iowa (6.4% [3.7%, 9.1%]), while Minnesota was intermediate (10.0% [6.4%, 13.7%]) and not different than the other states. Similar state differences were found for farmers who planted a cover crop in the fall of 2005, only estimates of cover crop use were lower (Illinois = 11.0% [7.1%, 14.9%], Indiana = 11.9% [7.8%, 16.0%], Iowa = 4.8% [2.4%, 7.2%], and Minnesota = 5.1% [2.4%, 7.8%]).

Results from logistic regression for the proportion of farmers that had ever used cover crops indicate that the number of crops grown on a farm was a significant (p-value < 0.05) factor affecting cover crop use for each state except Iowa. In Illinois, the odds of using cover crops was 2.98 (1.93, 4.62)

Table 1
Maximum likelihood estimates for parameters and tests for significance in predicting whether or not farmers ever used cover crops in Illinois (n = 209).

Regression parameters	Estimate	se	Chi-square	*p*-value	Odds ratios	95% confidence limits
Years farming	0.006	1.11	0.13	0.716	1.01	(0.98, 1.04)
Education > high school	0.129	0.40	0.10	0.747	1.14	(0.52, 2.50)
Proportion land owned	0.079	0.21	0.14	0.710	1.10	(0.72, 1.63)
Number of crops	1.093	0.22	23.9	<0.001	2.98	(1.93, 4.62)
Enrolled in government program	0.469	0.39	1.46	0.226	1.60	(0.75, 3.42)
Soil improvement	0.886	0.56	2.52	0.112	2.43	(0.81, 7.24)
Yield advantage	0.758	0.40	3.67	0.056	2.13	(0.98, 4.64)

Table 2
Maximum likelihood estimates for parameters and tests for significance in predicting whether or not farmers ever used cover crops in Indiana (n = 213).

Regression parameters	Estimate	se	Chi-square	*p*-value	Odds ratios	95% confidence limits
Years farming	0.013	0.01	0.83	0.363	1.01	(0.99, 1.04)
Education > high school	-0.145	0.34	0.17	0.678	0.87	(0.45, 1.69)
Proportion land owned	0.312	0.30	1.08	0.298	1.37	(0.76, 2.45)
Number of crops	0.449	0.15	8.96	0.003	1.57	(1.17, 2.10)
Enrolled in government program	0.901	0.32	7.82	0.005	2.47	(1.31, 4.66)
Soil improvement	0.631	0.46	1.89	0.170	1.88	(0.76, 4.63)
Yield advantage	0.574	0.34	2.77	0.096	1.78	(0.90, 3.49)

higher for each crop added to the farming operation (table 1), while in Indiana and Minnesota, odds ratios for an additional crop were about 1.6 (1.17, 2.10) and 1.9 (1.26, 2.82) (tables 2 and 4). Indiana respondents were also more likely to use cover crops if they participated in a government conservation program (table 2). In Illinois, Indiana, and Minnesota, suggestive but inconclusive evidence from the maximum likelihood estimates indicated farmers may be more likely to use cover crops if they perceived a yield advantage (tables 1, 2, and 4).

Although the maximum likelihood analysis did not provide strong evidence that farmers would use cover crops if they perceived a yield advantage, 18% to 35% of farmers in the region perceived a yield advantage from using cover crops (table 5). Cover crop effect on grain and seed yield varies. Miguez and Bollero (2005) using a meta analysis reported that grass winter cover crops neither increased nor decreased corn yield, while legumes increased corn yield when no N fertilizer was applied and this benefit decreased with application of N fertilizer. Eckert (1988) and Johnson et al. (1998) reported a 3% and 17% corn yield reduction using a rye (*Secale cereale* L.) cover crop in Ohio and Iowa in a corn–soybean rotation. Soybean yield following a rye cover crop has been reported to be similar or different than a no rye check, depending on year and management (Eckert 1988; Ruffo et al. 2004). The question on our survey was not specific to plant functional group. The majority of farmers use small grains as cover crops (rye, oat, *Avena sativa* L., and wheat), although red clover (*Trifolium pratense* L.) was used more often in Illinois and Indiana.

Similarly, the maximum likelihood analysis did not provide evidence that farmers would use cover crops if they perceived a soil improvement advantage, although 71% to 80% (table 5) of farmers in the region perceived a soil improvement from using cover crops. The soil improvement variable combined increasing soil organic matter or decreasing soil compaction. Although cover crops are purported to increase soil organic matter or soil carbon, there is little evidence to support these claims in the US corn belt (Eckert 1991; Kaspar et al. 2006). We also asked respondents about whether cover crops reduce soil erosion, increase water infiltration, and decrease runoff. Responses to these three questions were combined into the soil water advantage variable (table 5). This variable did not appear in the regression model because respondents overwhelmingly and uniformly felt this was an important function of cover crops (97% to 99%).

An estimated 80.1% (77.7%, 82.5%) of farmers in the entire region use conservation practices. But only 42.7% (39.7%, 45.7%) of those who use conservation practices participated in government conservation programs in 2006. An estimated 42.6% (39.2%, 46.1%) of producers used conservation practices with cost-sharing incentives, while 57.1% (51.7%, 62.5%) employed conservation practices without incentives. Conservation practices were not defined, but examples like conservation tillage, waterways, spring vs. fall nitrogen application were listed as examples. About 60% of farmers in this region had moderate to very familiar knowledge of cover crops. Approximately 91% of farmers who had ever used cover crops (18% of all farmers) had moderate to very familiar knowledge of cover crops. Soil erosion (95.6% [94.7%, 97.2%]) and adding soil organic matter (74.4% [71.6%, 77.2%]) were the most important reasons for using cover crops. Reasons for not using them included too much time involved (34.8% [31.5%, 38.3%]), too costly (27.4% [24.2%, 30.5%]), do not have a runoff problem (28.1% [25.0%, 31.3%]), already use no-tillage practices (38.6% [35.2%, 42.0%]), and do not know enough about them (39.5% [36.1%, 43.1%]).

Planting cover crops after full-season

Table 3
Maximum likelihood estimates for parameters and tests for significance in predicting whether or not farmers ever used cover crops in Iowa (n = 249).

Regression parameters	Estimate	se	Chi-square	p-value	Odds ratios	95% confidence limits
Years farming	-0.008	0.02	0.20	0.658	0.99	(0.96, 1.03)
Education > high school	0.476	0.44	1.15	0.284	1.61	(0.67, 3.84)
Proportion land owned	0.345	0.33	1.09	0.297	1.41	(0.74, 2.70)
Number of crops	0.355	0.20	3.01	0.083	1.43	(0.96, 2.13)
Enrolled in government program	0.181	0.42	0.18	0.665	1.20	(0.53, 2.72)
Soil improvement	-0.135	0.47	0.08	0.775	0.87	(0.35, 2.20)
Yield advantage	0.412	0.50	0.67	0.411	1.51	(0.57, 4.03)

Table 4
Maximum likelihood estimates for parameters and tests for significance in predicting whether or not farmers ever used cover crops in Minnesota (n = 215).

Regression parameters	Estimate	se	Chi-square	p-value	Odds ratios	95% confidence limits
Years farming	0.025	0.02	1.76	0.185	1.03	(0.99, 1.06)
Education > high school	0.811	0.43	3.52	0.061	2.25	(0.97, 5.25)
Proportion land owned	-0.177	0.40	0.20	0.655	0.84	(0.39, 1.82)
Number of crops	0.633	0.21	9.49	0.002	1.88	(1.26, 2.82)
Enrolled in government program	-0.198	0.39	0.26	0.608	0.82	(0.39, 1.75)
Soil improvement	-0.671	0.45	2.23	0.135	0.51	(0.21, 1.23)
Yield advantage	0.723	0.43	2.86	0.091	2.07	(0.89, 4.79)

summer annual crops presents a challenge. Systems have been developed for establishing cover crops prior to leaf-drop in soybean (Johnson et al. 1998), while time constraints following sweet corn, seed corn, and silage corn are usually not as critical. Following corn for grain presents a serious challenge in the upper Midwest because much of the acreage is not typically harvested until October and November. Aerial seeding into grain corn before harvest is more variable and dependent on rainfall and cool temperatures for success (Tom Kaspar, personal communication, 2007). Approximately 55.7% (52.4%, 59.1%) of farmers would use cover crops if cost-sharing was available and would require on average a minimum payment of \$56.81 ha^{-1} (\$51.87 ha^{-1}, \$62.49 ha^{-1}) (\$23.20 ac^{-1} [\$21.0 ac^{-1}, \$25.3 ac^{-1}]). Farmers acknowledged the importance of cover crops for reducing soil erosion but did not mention the role cover crops play in accumulating nutrients. Additional educational efforts could focus on the role of cover crops in reducing nutrient losses, particularly nitrogen, in summer annual cropping systems.

Farmers in the study region farmed 309 ha (288 ha, 330 ha) (764 ac [712 ac, 816 ac]), of which approximately 124 ha were owned and 186 ha were rented. Farmers in the region had an average of 32.8 years (32.0 years, 33.6 years) of farming experience and 69.4% (66.6%, 72.2%) did not work off of the farm. An estimated 58.6% (55.7%, 61.7%) of farmers raised crops only and 40.4% (37.4, 43.4) raised crops and livestock. Approximately 47.1% (40.0%, 54.3%) of farmers who ever used cover crops raised only crops and 51.6% (44.5%, 58.7%) raised crops and livestock compared to 61.2% (58.0%, 64.6%) crops only and 37.9% (34.7%, 41.2%) crops and livestock for those who had never used cover crops. The average number of crops ranged from 2.55 to 2.65 across the four states. Across the study region, the majority of farmers' acreages were in grain or silage corn, seed corn, soybean, and wheat, although sweet corn, oat, and hay crops were also grown.

Farmers in the study region who planted cover crops in the fall of 2005 (8%) planted them on an average of 16.9 ha (7.7 ha, 26.2 ha) 41.7 ac (18.9 ac, 64.6 ac), which represents a small fraction (6%) of the land for the average size farm. Additional questions were not posed about how land that was planted to cover crops was selected. If cover crops are planted on a limited basis, additional research could address the prioritization of land that is seeded to cover crops to maximize their effectiveness. Cover crops perform an important role in conserving natural resources, particularly in farming systems dominated by summer annual crops. However, incorporating them into summer annual cropping systems, especially following corn grain in the upper Midwest, presents challenges because of the short establishment window after grain harvest limited by temperature and possibly water.

If corn acreage increases in response to current and new markets, the need for cover crops for soil protection and nutrient cycling will also increase. The results of this survey quantify current perceptions about cover crops and their perceived role in Midwest farming systems. Farmers were asked if they had enough information about cover crops to make decisions about their selection, management, and use. Only 54% of respondents answered yes to this question. Information on the cost of using cover crops was listed as an important item. Developing and disseminating cost estimates for cover crop systems should be targeted by researchers and educators to fill this information gap.

Significantly more farmers who had used cover crops indicated that they used conservation practices (86%) compared to farmers who had never used cover crops (79%) (p-value = 0.02, table 6). Results also indicate that farmers who planted cover crops grew more crops (p-value < 0.001) and were more

Table 5
Means and standard errors for the explanatory variables used in the logistic regression model for Illinois, Indiana, Iowa, and Minnesota.

	Illinois			Indiana			Iowa			Minnesota		
Variable	***n***	**Mean**	**se**	***n***	**Mean**	**se**	***n***	**Mean**	**se**	***n***	**Mean**	**se**
Years farming	251	33.2	0.8	250	33.5	0.8	309	32.7	0.7	265	31.9	0.8
Percent with more than high school education	257	59.1	3.1	251	59.8	3.1	316	46.4	2.8	268	55.6	3.0
Proportion of land owned	252	0.54	0.06	247	0.62	0.03	308	0.59	0.03	261	0.68	0.04
Number of crops	248	2.62	0.06	243	2.65	0.07	299	2.55	0.05	260	2.65	0.06
Percent enrolled in government program	251	49.8	3.2	241	45.2	3.2	313	59.1	2.8	259	52.8	3.1
Percent perceived soil improvement	231	80.1	2.6	234	79.9	2.6	274	70.9	2.7	237	76.8	2.7
Percent perceived yield advantage	231	32.0	3.1	234	35.4	3.1	274	17.9	2.3	237	27.9	2.9
Percent perceived soil water advantage	231	96.5	1.2	234	97.4	1.0	274	99.3	0.5	237	97.0	1.1

Table 6
Descriptive statistics and significance tests for farmers in the study region who used cover crops compared to farmers who never used cover crops.

	Used cover crops			Never used cover crops				
Variable	***n***	**Mean**	**se**	***n***	**Mean**	**se**	***Z*-statistic**	***p*-value**
Acres farmed	200	883	73	870	742	28	1.79	0.07
Number of crops	192	3.12	0.08	843	2.51	0.03	7.26	<0.001
Percent who implemented conservation practices	167	86.0	2.5	674	79.2	1.4	2.37	0.02
Percent receiving incentives who would adopt conservation practices without incentives	43	60.8	5.9	150	56.3	3.1	0.68	0.50
Percent only growing crops	95	47.1	3.6	533	61.3	1.7	-3.57	<0.001
Percent growing crops and raising livestock	100	51.6	3.6	326	37.9	1.7	3.44	0.001

likely to farm with crops and livestock (*p*-value = 0.001) than those who never used cover crops. Featherstone and Goodwin (1993) surveyed Kansas farmers about the factors influencing their decision to invest in long-term conservation programs and found that older farmers invest less in conservation, farmers whose farms are corporately organized make larger conservation investments, and participation in government programs does not affect the investment in long-term conservation improvements.

In this survey, cover crop use increased only in Indiana if respondents participated in government conservation programs. The results also indicated that respondents had 33 years of farming experience and that farmers are raising crops on more rented or leased than owned land. It remains unclear how absentee land owners will influence decisions about land use and conservation in the future.

Summary and Conclusions

An estimated 18% of farmers in this region have ever used cover crops, 11% in the last five years, and 8% planted cover crops in the fall of 2005. Crop diversity was the most consistent and important factor related to the use of cover crops. Corn belt farmers responded that cover crops are most effective at reducing soil erosion (96%) and increasing soil organic matter (74%). Approximately 56% of farmers indicated that they would plant cover crops if cost-sharing was available. Although farmers in this region are familiar with the main benefits of cover crops, educational programs focused on cover crop cost, selection, and management should be targeted to fill information gaps. Increasing cover crop use in summer annual dominated farming systems could have significant conservation benefits to soil, water and air.

Acknowledgements

This research was partially funded by the Leopold Center for Sustainable Agriculture, Iowa State University.

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