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Demographic and Management Factors Affecting the Adoption and Perceived Yield Benefit of Winter Cover Crops in the Southeast

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The inclusion of cover crops in cropping systems brings direct and indirect costs and benefits. Farmers will adopt and utilize cover crops as long as the perceived benefit of using them is positive. This paper examines the demographic and management factors affecting the adoption and perceived benefit (in terms of improved crop yield) of using winter annual cover crops. A double selectivity model of cover crop adoption and perceived yield gain was estimated using survey data of Alabama farmers examining cover crop use and management. Results may help in understanding factors shaping farmers' perceptions, adoption, and retention of cover crops.

Key Words: adoption, conservation, cover crops, double selectivity model, perceived yield gain, tobit model

JEL Classifications: Q12, Q15, Q55

The inclusion of cover crops in cropping systems brings both direct and indirect costs and benefits. A cover crop is a brassica, small grain, grass, legume, or mixture of these that is grown in rotation between regular cash crop production periods that provide soil protection and improvement (Singer, Nusser, and Alf, 2007; Soil Science Society of America, 1997). Agronomic literature has shown that cover crops can help alleviate drought stress by increasing infiltration rates and soil moisture content as well as improve soil quality by helping to relieve soil compaction, improving soil organic matter, and reducing soil erosion (Reeves, 1994; Sustainable Agriculture Network, 1998). Other benefits can include weed suppression, protecting water quality, increasing nutrient cycling efficiency, and potentially improving cash crop productivity. Costs of using cover crops can include increased direct costs for planting and management, loss in crop revenue if cover crops interfere with cash crop production, slow soil warming, and difficulties in predicting nitrogen

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mineralization (Snapp et al., 2005). Cover crops have the potential to increase or decrease the profitability of cropping enterprises.

The primary economic benefits of using cover crops are a potential yield benefit and reduced production risk (Jaenicke, Frechette, and Larson, 2003; Larson et al., 2001; Roberts et al., 1998). These benefits are dependent upon how the cover crop is managed. For example, Morton, Bergtold, and Price (2006) provide some preliminary findings that maximizing cover crop biomass production may be a key management consideration in optimizing the economic benefit of winter grain cover crops for the following cash crop. The benefit is realized in cash crop and soil productivity, which may or may not result in gains in crop yield. Farmers will adopt and continue to use cover crops in their production systems if the perceived net benefit is positive. A significant component of the perceived net benefit is the perceived yield gain. Although this component alone does not serve as a proxy for the net benefits from adopting cover crops, it can provide a measure of the direct revenue gains from a gain in the proceeding cash crop's yields, which can play a significant factor in farmers' choices to use a cover crop or not. The perceived yield benefit of a cover crop will be influenced by demographic, economic, and management factors.

Singer, Nusser, and Alf (2007) examined the adoption of cover crops by farmers in the U.S. Corn Belt. They found that the number of crops grown, conservation program participation, level of education, and potential yield advantage all played a role in the likelihood a farmer would adopt cover crops. A review by Snapp et al. (2005) of discussions with farmers concerning cover crops highlights the significance of recognizing the opportunity costs of planting cover crops that may replace or limit the type of cash crops grown in rotation. Lichtenberg (2004) found that a 1% increase in the cost of a cover crop can reduce the adoption of cover crops by up to 14% among Maryland farmers. Determining the factors that affect farmers' perceptions during the adoption process may help policymakers and conservation advocates in developing conservation programmatic efforts and outreach that promote the use of cover crops as a soil conservation measure to meet societal goals. Adoption is a continual process, by which farmers are continually evaluating the performance of adopted technologies, and modifying practice usage accordingly (Pannell et al., 2006). Farmers' perceived performance of the yield benefits of cover crops can serve to promote further adoption by these farmers and assist with the adoption by farmers in their social networks (Pannell et al., 2006).

The purpose of this paper is to examine the demographic and management factors affecting the adoption and perceived yield benefits of cover crops by farmers in the Southeast. A double selectivity model of cover crop adoption and perceived yield gain was developed following Khanna (2001). The model examines cover crop adoption, farmers who perceived a yield benefit after adoption, and the perceived level of the yield benefit. The model is estimated using survey data of Alabama farmers examining cover crop use and management. Results of demographic and management variables affecting the adoption of cover crops, the presence of a perceived yield benefit, and the level of that benefit are presented.

Research Methods and Data

Data

Data were obtained from a mail survey about cover crop adoption, experience, and management developed in conjunction with Auburn University and U.S. Department of Agriculture (USDA), Agricultural Research Service. The survey was administered by the USDA, National Agricultural Statistics Service (NASS), Alabama State Office to Alabama row crop producers in November 2007. The survey instrument was reviewed by cover crop experts for key management issues and relevance, as well as field tested with farmers for relevance and to ensure respondents would understand questions asked. The survey was sent to all qualified farmers with at least 150 acres of row crop production and greater than $50,000 in gross farm sales using 2002 Agricultural Census Data, which amounted to 1,312 farmers across the state. The sample population represented the entire set of farmers meeting the specified conditions in the state of Alabama. The survey was administered by mail to 1,162 farmers and was delivered to the remaining 150 farmers by field enumerators to be mailed back (due to correspondence with other USDA-NASS surveys being conducted at that time). The mailing included the survey, an information sheet about cover crops, and a letter from Auburn University asking them to participate in the survey. A phone call reminder was made 1 week after the first mailing to ask potential respondents to complete the sent survey. Three weeks after the initial mailing, a second mailing of the survey was sent out, excluding any mail returns from the first round. A phone follow-up was performed again 1 week after this mailing with the opportunity to do the survey over the phone. The number of completed surveys was 362 (response rate of 28%), of which, 301 surveys were usable for this study.[1] Thus, the data set represents 23% of the entire population of row crop producers meeting sampling criteria in the state of Alabama, as well as approximately 19% of all farm land devoted to cash crop production. Comparing summary statistics using 2007 census data of survey respondents to the sample population provides support for the representativeness of the data set collected. These summary statistics are provided in Table 1.

Data collected on the survey included conservation practices used on farm, characteristics of the farming operation, cover crop use and management, willingness to produce cover crops, and farmer demographics. Definitions and summary statistics of the variables developed from the survey and used for econometric modeling are presented in Table 2. The dependent variable "Adopt" came from a question asking if farmers had planted a cover crop in the past 3 years. Data for the dependent variable DYINC came from a question asking if the farmer perceived a yield gain in their cash crop from using a cover crop, and if farmers had adopted cover crops in the past 3 years. Data for the last dependent variable, ΔY, the perceived yield gain from using a cover crop, was obtained from a question conditional on the requirement that the farmer perceived a yield gain, asking them to indicate the perceived magnitude of the yield gain (as a percent) and the corresponding cash crop. The variable ΔY was then calculated as a weighted average (based on crop acreages) of the percentage gain across all identified cash crops. No observed data were collected if the farmer did not perceive a yield gain from a cover crop. Thus, ΔY is truncated at 0. Of the 301 respondents analyzed in this study, 200 respondents indicated that they had used cover crops in the past 3 years and 73 perceived a positive yield gain. Primary cash crops planted by farmers included corn, cotton, peanuts, and soybeans, with others planting millet, oats, sorghum, and wheat. Of the farmers surveyed, 68, 66, 53, and 41 of the respondents planted corn, cotton, peanuts, and soybeans, respectively. Of those who adopted cover crops, 63, 63, 45, and 43 planted corn, cotton, peanuts, and soybeans, respectively. Cover crop varieties planted included winter wheat, cereal rye, ryegrass, clover, millet, hairy vetch, oats, triticale, lupine, Austrian winter pea, and mixtures of these.

The other model variables included: (i) farm characteristics; (ii) farm/management practices; (iii) demographic variables; and (iv) farmers' perceptions about cover crops. Farm characteristics are likely to have different effects on the adoption and perception of cover crop performance as a conservation practice. The choice of cash crop and rotation will dictate the judicious selection of a winter cover crop (Dabney, Delgado, and Reeves, 2001; Snapp et al., 2005). For example, planting crimson clover prior to corn can help meet the demand for nitrogen by

[1] Unusable surveys consisted of those where respondents failed to answer questions that were used to derive the dependent and explanatory variables used in the empirical model. While the response rate is considered low, USDA-NASS in Alabama indicated that it was considerably higher than similar mail surveys conducted in the past. Furthermore, it was believed that survey response was lower due to timing of the survey, which may have coincided with a late crop harvest for certain fall cash crops, such as cotton. This limitation was taken into consideration, but it was determined that this timing was optimal given other large surveys to be administered by USDA-NASS in the near future (e.g., Agricultural Census and Agricultural Resource Management Survey), which may have resulted in even lower response rates if they coincided.

Table 1. Comparing Summary Statistics for Survey Respondents, Sample Population, and Entire Farmer Population Using 2002 and 2007 Agricultural Census Data

Variable	Survey Respondents (n = 301)	Sample Population[a] (n = 1312)	2007 Agricultural Census[b]
Age	55.5	58.1	54.9
Gross value of farm sales (as percent of sample size)			
< $50,000	9.0[c]	N/A	N/A
$50,000 to $99,999	19.3	10.2	29.8
$100,000 to $249,999	29.2	32.7	26.2
$250,000 to $499,999	21.6	25.8	16.0
$500,000 to $999,999	12.3	19.9	13.0
> $1,000,000	8.6	11.5	14.9
Ethnicity (as percent of sample size)			
Either White or Caucasian	98.3	96.4	97.1
Either Black or African American	1.0	1.7	0.01
American Indian	0.7	0.9	0.01
Other	0.0	1.0	0.01
Row crop acreage	781	878	604[d]

Sources: U.S. Department of Agriculture, National Agricultural Statistics Service (2002 and 2007).

[a] These statistics were calculated by USDA-NASS for the sample population using 2002 Agricultural Census survey data.

[b] 2007 Agricultural Census averages for age and ethnicity represent all farms with crop land and sales greater than $50,000 in gross farm sales. Averages for gross value of farm sales and row crop acreage are based on farms with greater than 100 acres of land and $50,000 in gross farm sales.

[c] While the sample population was not sampled for a farm with less than $50,000 in gross farm sales, the determination was based on 2002 Agricultural Census Data and some farms had gross sales fall below this threshold since 2002.

[d] For the 2007 Agricultural Census, this statistic was calculated by taking the average of cropland acres using the acreage midpoints in the ranges: (i) 100 to 199; (ii) 200 to 499; (iii) 500 to 999; (iv) 1,000 to 1,999; (v) 2,000 and above times the number of farms falling in each category from the sales categories given above, weighted appropriately.

N/A, not applicable.

the following corn crop. Higher farm sales will likely increase the potential of cover crop adoption by lowering potential risks, allowing for more experimentation, thereby increasing the expectations of performance (Abadi Ghadim and Pannell, 1999; Soule, 2001; Soule, Tegene, and Wiebe, 2000). Farm size can potentially play a significant factor in the adoption of cover crops (Bergtold, Anand, and Molnar, 2007), but may have a negative impact on the perceived benefit of cover crops due to potential resource restrictions from scarce labor and time for planting and managing a cover crop. Farmers are likely to be more hesitant about placing new conservation practices on rented land, but may do so if they can provide (immediate) short-term benefits (Carolan et al., 2004). Greater farm experience may increase or decrease the expected benefits of a cover crop due to past experiences with other conservation practices, effect on risk aversion, and improvements in farmers' skills (Abadi Ghadim and Pannell, 1999).

Farming, conservation, and cover crop management will have a significant effect on the adoption and performance of cover crops. It is hypothesized that farmers who participate in federal conservation programs, such as the Environmental Quality Incentives Program or Conservation Security (Stewardship) Program, are more likely to adopt cover crops. Furthermore, the opportunity of financial cost share assistance for cover crops from these programs is likely to increase the perceived benefit of cover crops, as it lowers the cost and risk faced by the farmer in using the practice. Along these same lines, farmers who have conservation plans should be more likely to adopt conservation practices than those that do not (Wu and Babcock, 1998). Use of conservation tillage and past conservation efforts are likely to increase the probability of adopting cover crops

Table 2. Variable Definitions and Summary Statistics

Variable	Description	Mean/Frequency[a] Entire Sample (n = 301)	Mean/Frequency[b] Adopters (n = 200)	Mean/ Frequency[c] Adopters Who Perceived a Yield Increase (n = 73)
	Dependent Variables			
Adopt	Equal to "1" if cover crops were used in the past 3 years, "0" otherwise	0.66	—	—
DYINC	Equal to "1" if cover crops were adopted and the farmer perceived a yield gain in their cash crop from using a cover crop, "0" otherwise	—	0.37	—
ΔY	Perceived gain in yield as a weighted percentage across crops from using a cover crop (truncated at 0)	—	—	12.77 (13.11)
	Farm Characteristics			
No rotation	Equal to "1" if farmer does not use a crop rotation, "0" otherwise	0.10	0.07	0.05
Peanuts	Equal to "1" if peanuts are grown and a cover crop increased perceived yield, "0" otherwise	0.45	0.53	0.53
Corn	Equal to "1" if corn is grown and a cover crop increased perceived yield, "0" otherwise	0.63	0.68	0.73
Cotton	Equal to "1" if cotton is grown and a cover crop increased perceived yield, "0" otherwise	0.63	0.66	0.74
Soybean	Equal to "1" if soybean is grown and a cover crop increased perceived yield, "0" otherwise	0.41	0.43	0.49
Farm size	Total acres owned plus rented (000s of acres)	1.14 (1.04)	1.25 (1.17)	1.37 (1.24)
Percent rent	Fraction of total acreage rented	0.60 (0.33)	0.61 (0.50)	0.68 (0.44)
Farm sales	Gross farm sales. Ordinal variable equal to "1" if < $50,000, "2" if between $50,000 and $99,999, "3" if between $100,000 and $249,999, "4" if between $250,000 and $499,999, "5" if between $500,000 and $999,999, and "6" if > $1 million.	1 – 0.09 2 – 0.19 3 – 0.29 4 – 0.22 5 – 0.12 6 – 0.09	1 – 0.06 2 – 0.18 3 – 0.30 4 – 0.22 5 – 0.14 6 – 0.12	1 – 0.03 2 – 0.12 3 – 0.29 4 – 0.27 5 – 0.12 6 – 0.16
Experience	Number of years farming	30.43 (11.82)	30.16 (31.40)	29.55 (30.27)

Table 2. Continued

Variable	Description	Mean/Frequency[a] Entire Sample (n = 301)	Mean/Frequency[b] Adopters (n = 200)	Mean/ Frequency[c] Adopters Who Perceived a Yield Increase (n = 73)
	Farm and Conservation Practices			
Plan	Equal to "1" if farmer has a conservation plan, "0" otherwise	0.78	0.83	0.92
Program	Equal to "1" if farmer participates in EQIP or CSP, "0" otherwise	0.42	0.48	0.49
Cost Share	Equal to "1" if farmer receives cost share assistance for planting cover crops, "0" otherwise	—	0.23	0.33
Irrigation	Equal to "1" if any cash crops are irrigated, "0" otherwise	0.21	0.27	0.29
Intensity[d]	Number of conservation practices used by farmer	1.80 (1.55)	1.95 (1.83)	2.21 (2.05)
Conservation tillage	Equal to "1" if use conservation tillage methods, "0" otherwise	0.69	0.72	0.77
Legume	Equal to "1" if a legume cover crop is planted, "0" otherwise	—	0.07	0.08
Credit N	Equal to "1" if a legume is planted and N applied to cash crop is decreased, "0" otherwise	—	0.14	0.18
Apply N	Equal to "1" if N is applied to cover crop, "0" otherwise	—	0.57	0.56
Timing	Equal to "1" if terminate cover crop 1 week or less prior to planting, "2" if terminate 2 weeks prior to planting, "3" if terminate 3 weeks prior to planting, and "4" if terminate 4 or more weeks prior to planting	—	1 – 0.11 2 – 0.32 3 – 0.26 4 – 0.33	1 – 0.10 2 – 0.36 3 – 0.29 4 – 0.26
Bale or graze	Equal to "1" if harvest cover crop residues or allow cattle to graze on cover crop residues, "0" otherwise	—	0.53	0.48
Max biomass	Equal to "1" if cover crop is managed to maximize the amount of biomass produced, "0" otherwise	—	0.52	0.67
	Demographics			
Off-farm income	Equal to "1" if any family members bring in off-farm income, "0" otherwise	0.52	0.53	0.53
Education	Level of education. Equal to "1" if some high school, "2" if have diploma or GED, "3" if trade school, "4" if some college, "5" if college graduate, "6" if postgraduate	1 – 0.04 2 – 0.35 3 – 0.03 4 – 0.24	1 – 0.03 2 – 0.37 3 – 0.02 4 – 0.27	1 – 0.04 2 – 0.34 3 – 0.03 4 – 0.29

Table 2. Continued

Variable	Description	Mean/Frequency[a] Entire Sample (n = 301)	Mean/Frequency[b] Adopters (n = 200)	Mean/ Frequency[c] Adopters Who Perceived a Yield Increase (n = 73)
		5 – 0.29 6 – 0.05	5 – 0.29 6 – 0.03	5 – 0.26 6 – 0.04
	Farmer Perceptions			
High cost	Equal to "1" if the farmer perceives cover crops as being a high cost conservation practice, "0" otherwise	0.53	0.52	0.47
Environmental benefits[e]	An ordinal variable indicating the number of environmental benefits the farmer perceives that cover crops provide	3.93 (1.92)	4.23 (3.68)	4.52 (3.89)

[a] For discrete data frequency of response is reported. For ordinal variables this includes the frequency for each response category when informative. For continuous variables the standard deviation is reported in parenthesis.
[b] These statistics are for the sub-population of cover crop adopters.
[c] These statistics are for the sub-population of cover crop adopters who perceived a yield gain in their cash crop from use of a cover crop.
[d] Practices include: filter/buffer strips, wildlife habitat, precision agriculture, crop nutrient management, and integrated pest management.
[e] Environmental benefits include reduced soil erosion, increased water storage, increased soil organic matter, weed suppression, reduced soil compaction, and decreased runoff.
EQIP, Environmental Quality Incentives Program; CSP, Conservation Security (Stewardship) Program.

(Bergtold, Anand, and Molnar, 2007), and prior experience with conservation tillage and other practices may have a positive effect on the perceived gains from a cover crop. Abadi Ghadim and Pannell (1999) indicate that experience with related agricultural innovations or practices will increase the value of the current innovation or practice being considered. Irrigation may be seen as beneficial, as potential concerns about water availability for the cash crop may be avoided (Dabney, Delgado, and Reeves, 2001).

Increased cover crop biomass on the soil surface can provide greater benefits to cash crop productivity, through greater weed suppression, water infiltration into the soil, water conservation, improvements in nutrient cycling, and improvements in soil organic matter build-up, thereby increasing soil productivity and improving the performance of the cash crop (Dabney, Delgado, and Reeves, 2001). Morton, Bergtold, and Price (2006) provide some preliminary evidence that increased cover crop biomass is needed to optimize the economic return from the cover crop. Thus, managing cover crops to maximize biomass should have a positive impact on the perceived benefits and yield gains of using a cover crop. Cover crop management practices, such as application of nitrogen (N) to the cover crop, are likely to be in support of maximizing biomass, and are expected to have the same impact on the perceived benefit and yield gains from cover crops. The effect of timing of termination is uncertain, as the interaction between maximizing biomass production, effect of lower soil temperatures due to increased cover, and termination method all affect the performance of the cover crop and following cash crop (Ashford and Reeves, 2003; Snapp et al., 2005).

Use of legumes can provide additional N for the following cash crop, reducing the need for commercial fertilizer. However, farmers may not adjust N fertilization rates to the cash crop immediately following the cover crop due to potentially limited availability of N provided by the cover crop or risk-averse behavior (Dabney, Delgado, and Reeves, 2001; Larson et al., 1998; Lu et al., 2000). Thus, the net benefit of using a legume cover crop may be lower if N fertilization rates are not adjusted accordingly to take account of the N provided by the cover crop.

Although it is assumed that the primary benefit of cover crops is a boost in cash crop yields, farmers may choose to winter annual graze or harvest (for hay or grain) the cover crop for additional income. The potential impact on the perceived yield benefit is expected to be positive. While cover crop residue levels may decrease with winter annual grazing or harvesting, agronomic evidence shows that the cover crops still may provide a yield boost relative to cash crop yields with no cover crop (Siri-Prieto, Reeves, and Raper, 2007).

The impact of demographic factors on the expected performance of cover crops is somewhat unclear. Gould, Saupe, and Klemme (1989) found a negative relationship between the adoption of conservation tillage practices and off-farm income, potentially due to the limited amount of time a farmer may have to invest in conservation practices on-farm. For cover crops, this may constrain a farmer's ability to gain information about cover crops, skewing his expectations about their potential benefits. Education is likely to have a positive impact on the adoption of conservation practices (Featherstone and Goodwin, 1993) by affecting expectations and risk attitudes toward conservation efforts and protecting the environment.

Farmers' perceptions toward cover crop costs and environmental benefits will play a significant role in forming their expectations. High costs are likely to decrease the adoption of cover crops by farmers. Lichtenberg (2004) estimated that a 1% increase in the cost of cover crops would decrease the probability of adopting cover crops by 14% for Maryland farmers. Thus, it would seem that as costs increase, the perceived benefit of adopting a cover crop will decrease. Pannell (1999) indicates that agricultural innovations not only have to provide benefits in excess of input costs, but must also cover opportunity costs. Snapp et al. (2005) states that the biggest internal cost to the farmer of adopting cover crops is the opportunity cost of income foregone from potential cash crop production. Given the ability to double and possibly triple a crop (i.e., in vegetable production systems), cover crops may replace a cash crop, which could have significant opportunity costs. It is expected that farmers with more experience managing cover crops should cite more environmental benefits from their use, having a positive impact on the perceived gain from using cover crops.

Model

A model of cover crop adoption and perceived yield benefit was developed following the framework presented in Khanna (2001). The model has three stages following the question format asked in the survey. In the first stage, the cover crop adoption decision by row crop producers is examined. In the second stage, farmers' perceptions of a yield benefit from the cover crop are examined for those who adopted a cover crop. In the third stage, if a farmer perceived a yield benefit, then the factors affecting the magnitude of the perceived gain in cash crop yields (yield benefit) are modeled. Results from Singer, Nusser, and Alf (2007) suggest that farmers may be more likely to use cover crops if there is a perceived yield benefit. Given that farmers are continually re-evaluating technologies on-farm, they will likely retain the use of cover crops as long as the perceived yield benefit is positive. Given that the second and third stages of the model are only observable for producers who have adopted cover crops, sample selection bias may result. To correct for any potential bias, a double selectivity model is used to account for the sequential nature of the second and third stages.

Following the switching regression set-up by Fuglie and Bosch (1995), we let the cover crop adoption decision be a dichotomous choice resulting from a latent utility maximization problem. Consider the expected utility function $V_j(\boldsymbol{X_A})$ for $j = c,n$, where $\boldsymbol{X_A}$ is a set of explanatory variables related with the decision of whether or not to adopt a cover crop, c represents the state where cover crops are adopted, and n represents the state where cover crops are not adopted. A producer adopts cover crops if $\Delta V = V_c(\boldsymbol{X_A}) - V_n(\boldsymbol{X_A}) > 0$. The quantity ΔV is not directly observed, but instead whether or not the producer adopts cover crops is. Denote the decision to adopt as A, where A equals "1" if $\Delta V > 0$ and "0" otherwise. The decision to adopt is determined by a set of exogenous variables $\boldsymbol{X_A}$ where $\boldsymbol{X_A}$ is a $(K_A \times 1)$ vector of variables, including farm characteristics, farm/management practices, demographic variables, and farmers' perceptions about cover crops (see Fuglie and Bosch, 1995; Pannell et al., 2006). Then, a model of cover crop adoption for the i^{th} producer can be specified as:

$$(1) \quad \Delta V_i = \boldsymbol{\alpha}'X_{A,i} + \varepsilon_i \text{ with } \varepsilon_i \sim NI\left(0, \sigma_\varepsilon^2\right) \text{ and } A_i = \begin{cases} 1 & \text{if } \Delta V_i > 0 \\ 0 & \text{otherwise} \end{cases},$$

where $\boldsymbol{\alpha}$ is a vector of parameters.

Past agronomic literature has shown the potential yield benefits of using cover crops prior to cash crop planting (see Fageria, Baligar, and Bailey, 2005; Miguez and Bollero, 2005; Parvin and Dabney, 2004). Yield benefits in the form of yield gains and yield stabilization over time (e.g., reductions in potential future losses) partially result from improved soil productivity, reduced soil erosion, weed suppression, and improved nutrient cycling. Other benefits may accrue from the use of cover crops, including overwintering of wildlife, reductions in nutrient leaching, and improvements in water quality, that provide additional benefit to the farmer and society (Lu et al., 2000; Snapp et al., 2005). Thus, the perceived benefit from the use of a cover crop by a farmer will include benefits from a number of sources, which includes the perceived yield benefit, which is the focus in this study.

Lu et al. (2000) recognize that while cover crops can reduce input costs (e.g., fertilizer and herbicides) for the cash crop, the reduced costs may not be enough to offset the increased expense from planting the cover crop. If a farmer adopts a cover crop (i.e., $\Delta V_i > 0$), then the farmer will perceive a yield benefit or not from the use of that cover crop, which may affect his/her future cover crop management decisions. A perceived yield benefit could improve the likelihood of a farmer retaining the use of the cover crop on-farm due to the perceived potential of additional cash crop revenue, which could help cover the expense of adopting the cover crop. To model this, let $D_i = 1$ if a farmer who adopted cover crops perceived a yield benefit, and $D_i = 0$ otherwise. A farmer's perception of a yield benefit will be dependent on a set of exogenous factors, that is,

$$D_i = \beta' X_{D,i} + v_i \text{ with } v_i \sim NI(0, \sigma_v^2) \text{ and}$$
$$(2) \quad D_i = \begin{cases} 1 \text{ if } A_i = 1 \text{ and the farmer perceived a yield benefit} \\ 0 \quad \text{otherwise} \end{cases},$$

where $\boldsymbol{\beta}$ is a vector of parameters and $X_{D,i}$ is a set of explanatory variables that include farm characteristics, farm/management practices, demographic variables, and farmers' perceptions about cover crops related to a farmer's perception of the yield benefit from the use of a cover crop.[2]

Now assume that ε_i and v_i have a bivariate normal distribution with mean vector zero and covariance matrix $\sum = \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}$. Hence, $\sigma_\varepsilon^2 = \sigma_v^2 = 1$ and $\text{Cov}(\varepsilon_i, v_i) = \rho$, given that the random factors affecting the adoption of cover crops and the perceived yield benefits are not independent. Given that D_i is only observed if $A_i = 1$, a modified version of the bivariate probit model is used to estimate this sequential process following Khanna (2001) and Hausman and Wise (1978). Only three outcomes can be observed in the data, that is: (i) $A_i = 1$ and $D_i = 1$; (ii) $A_i = 1$ and $D_i = 0$; or (iii) $A_i = 0$. Based on these outcomes, a bivariate sequential probit model is estimated with the following probabilities of the three outcomes (Khanna, 2001):

$$(3) \quad P_{11} = \Pr(A_i = 1, D_i = 1) = \Phi_2(\alpha' X_{A,i}, \beta' X_{D,i}, \rho)$$

$$(4) \quad P_{10} = \Pr(A_i = 1, D_i = 0) = \Phi(\alpha' X_{A,i}) - P_{11}$$

$$(5) \quad P_{00} = \Pr(A_i = 0) = 1 - \Phi(\alpha' X_{A,i}),$$

where $\boldsymbol{\Phi}$ and $\boldsymbol{\Phi}_2$ are the cumulative distribution functions of the standard normal and standard bivariate normal distributions, respectively. Marginal effects affecting the likelihood of adopting a cover crop and perceiving a yield benefit if a cover crop has been adopted are estimated following Greene (2003) with associated standard errors found using the delta method. Marginal effects are calculated at the means of the explanatory variables. The bivariate probit model and marginal effects were estimated using LIMDEP 9.0 (Econometric Software, Inc., Plainview, NY).

Adoption is a continuous process, under which farmers are continually re-assessing the technologies incorporated into their crop production systems (Pannell et al., 2006). If the i^{th} adopter perceived a yield benefit (i.e., $D_i = 1$), then the magnitude of that benefit will be important in determining if the conservation practice will be retained or modified in the future. The positive perceived yield benefit from the adopted cover crop is modeled as:

$$(6) \quad \Delta Y_i = \gamma' X_{Y,i} + u_i, \; u_i \sim \text{NI}(0, \sigma_u^2),$$

where $\boldsymbol{\gamma}$ is a vector of parameters and $X_{Y,i}$ is a $(K_Y \times 1)$ vector of explanatory variables related to the management of the cover crop that affect the level of the perceived yield benefit. Recall that ΔY is only observed for cover crop adopters who perceived a yield benefit. Thus, the conditional mean of ΔY_i will be conditional on the sample selection rule: $A_i = 1$ and $D_i = 1$. That is, the conditional mean of ΔY_i will be $E(\Delta Y_i|X_i, A_i = 1, D_i = 1) = \boldsymbol{\gamma}' X_{Y,i} + E(u_i|X_{Y,i}, A_i = 1, D_i = 1)$ (Khanna, 2001). To estimate Equation (6), the model must take into account the sample selection rule using the bivariate sequential probit model given by Equations (1) to (5).

Given that ΔY_i is truncated from below (i.e., $\Delta Y_i > 0$), Equation (6) is treated as a tobit regression model. In this case, the conditional mean of ΔY_i takes the modified form taking into account the sample selection rule (Greene, 2003 and Khanna, 2001):

$$(7) \quad \begin{aligned} &E(\Delta Y_i | \Delta Y_i > 0, X_{Y,i}, A_i = 1, D_i = 1) \\ &= \gamma' X_{Y,i} + \sigma_A \lambda_{A,i} + \sigma_D \lambda_{D,i} \\ &+ \sigma_\xi \frac{\phi(-\gamma' X_{Y,i}/\sigma_\xi)}{1 - \Phi(-\gamma' X_{Y,i}/\sigma_\xi)}, \end{aligned}$$

where

[2] The set of explanatory variables included in X_D includes variables specific to farmers' perceptions of the yield benefits they received from the use of a cover crop (see Table 2). These variables include the cash crop grown after the cover crop and specific cover crop management practices. The data for these variables were collected on the survey only for respondents who adopted a cover crop.

$$E(u_i|\boldsymbol{X}_{Y,i},\mathrm{A}_i=1,\,D_i=1) = \sigma_A\frac{\phi(\alpha'\boldsymbol{X}_{A,i})\phi(\beta'\boldsymbol{X}_{D,i}-\rho[\alpha'\boldsymbol{X}_{A,i}])}{P_{11}} + \sigma_D\frac{\phi(\beta'\boldsymbol{X}_{D,i})\phi(\alpha'\boldsymbol{X}_{A,i}-\rho[\beta'\boldsymbol{X}_{D,i}])}{P_{11}} = \alpha_A\lambda_{A,i}+\sigma_D\lambda_{D,i};$$

ϕ is the standard normal probability density function; $\boldsymbol{\Phi}$ is the standard normal cumulative density function; the term $\lambda_{A,i}$ corrects for the selectivity bias due to the choice of adopting cover crops; the term $\lambda_{D,i}$ corrects for the selectivity bias due to having a positive perception of the yield benefits from using cover crops; σ_ξ is the standard deviation of the error term; and the term ξ represents the normally distributed mean zero error term of the tobit model estimated (Khanna, 2001 and Tunali, 1986).

There exists the potential for variance heterogeneity across farms due to differences in farming characteristics, management experience, and cover crop perceptions. Thus heteroskedasticity may be present in the third stage of the model. To correct for this, the conditional variance of the tobit model is modeled as:

$$(8)\qquad \sigma^2_{\xi,i}=\sigma^2_\xi e^{\delta,W},$$

where $\boldsymbol{\delta}$ is a vector of parameters and $\boldsymbol{W}$ are socio-economic variables that include farm characteristics, management experience, and perceptions about cover crops (Greene, 2003).

Given the three-way classification of farmers in this study, Khanna (2001) suggests that a restriction on the vectors of explanatory variables in Equations (1) and (2) may be required (e.g., that the vectors of explanatory variables differ by at least one variable). As seen in Table 3, this condition is satisfied, as the vectors of explanatory variables in the two equations differ. The set of explanatory variables for Equation (2), $\boldsymbol{X}_D$, includes cover crop management and cropping variables specific to a farmer's perception of a yield benefit. While the explanatory variables in Equation (6) may be identical to the explanatory variables in the selection equations due to the nonlinearity of the λ terms, multicollinearity may still result in problems during estimation (Khanna, 2001 and Santori, 2003). The correlation between the explanatory variables and λ terms included in Equation (6) were examined, and no correlation was found to be greater than 0.64, with the majority being less than or equal to 0.25.

The model was estimated using a two stage approach following Khanna (2001) and Tunali (1986). First the bivariate sequential probit model given by Equations (1) to (5) was estimated as described above. Then the coefficient estimates from the bivariate sequential probit model were used to provide estimates of $\lambda_{A,i}$ and $\lambda_{D,i}$, which were used as instruments in the tobit regression model to correct for double selectivity bias. The tobit regression model given by Equations (6) to (8) was then estimated separately using LIMDEP 9.0.

Results and Discussion

Estimation results for the econometric models are provided in Tables 3 and 4. The significance of $\lambda_{A,i}$ (-6.28; $P = 0.0005$) and $\lambda_{D,i}$ (3.82; $p = 0.0038$) in Table 4 points to endogenous sample-selection, justifying the need for the sample selection correction used in developing the model framework. Furthermore, the significance of the explanatory variables in the conditional variance in Table 4 justifies the heteroskedasticity correction adopted to capture unobserved heterogeneity across farms. The remainder of the results will be examined for each stage of the model.

Stage One – Cover Crop Adoption

The first stage of the model can be thought of as a probit regression (type) model. The results in Table 3 indicate that the percent of rented land (percent rent; -0.70; $p = 0.024$), irrigation of crops (irrigation; 0.62; $p = 0.011$), and the perceived number of environmental benefits from cover crops (environmental benefits; 0.15; $p = 0.002$) all significantly affected the adoption of cover crops by Alabama row crop producers. Results support the findings from Carolan et al. (2004) that farmers are less likely to adopt conservation practices on rented land due to a perception of greater risk to returns and issues with landlords. Results indicate that on rented land farmers are approximately 20% less likely to adopt. On the other hand, farmers who irrigate

Table 3. Estimation Results for the Bivariate Probit Selection Model of Cover Crop Adoption and Perceived Yield Benefit

	Bivariate Probit Selection Model[a]			
	Cover Crop Adoption (A) Equation		Perceived Yield Benefit (D) Equation	
Variable	Parameter Estimate (Standard Error[b])	Marginal Effects[c] $\left(\frac{\partial P(A=1)}{\partial X_{A,i}}\right)$	Parameter Estimate (Standard Error[b])	Marginal Effects[d] $\left(\partial \mathbf{P}\frac{(D=1 \mid A=1))}{\partial X_{D,i}}\right)$
Intercept	0.27 (0.46)	—	−0.76 (0.73)	—
No rotation	−0.39 (0.28)	−0.13 (0.10)	0.20 (0.39)	−0.03 (0.24)
Peanuts	—	—	0.29 (0.19)	0.16 (0.11)
Corn	—	—	0.07 (0.21)	0.04 (0.12)
Cotton	—	—	0.10 (0.20)	0.06 (0.12)
Soybean	—	—	0.37* (0.18)	0.21* (0.10)
Farm size	0.03 (0.15)	0.02 (0.04)	−0.13 (0.13)	−0.06 (0.07)
Percent rent	−0.70** (0.31)	−0.20* (0.10)	0.31 (0.35)	−0.05 (0.19)
Farm sales	0.10 (0.10)	0.03 (0.03)	0.08 (0.10)	0.08 (0.05)
Experience	−0.01 (0.01)	−0.002 (0.003)	−0.002 (0.008)	−0.005 (0.004)
Plan	0.29 (0.22)	0.10 (0.08)	0.41 (0.27)	0.36 (0.21)
Program	0.28 (0.19)	0.08 (0.06)	−0.37 (0.20)	−0.12 (0.10)
Cost share	—	—	0.37 (0.21)	0.20 (0.11)
Irrigation	0.62** (0.24)	0.16** (0.07)	−0.20 (0.22)	0.06 (0.10)
Intensity	0.03 (0.06)	0.009 (0.02)	0.03 (0.06)	0.03 (0.03)
Conservation tillage	0.05 (0.19)	0.02 (0.06)	0.12 (0.20)	0.09 (0.10)
Legume	—	—	0.24 (0.42)	0.13 (0.23)
Credit N	—	—	0.16 (0.30)	0.09 (0.16)
Apply N	—	—	0.007 (0.18)	0.004 (0.10)
Timing	—	—	−0.009 (0.08)	−0.005 (0.05)
Bale or graze	—	—	0.04 (0.18)	0.02 (0.10)
Max biomass	—	—	0.34* (0.16)	0.19* (0.09)
Off-farm income	−0.08 (0.18)	−0.006 (0.06)	−0.15 (0.19)	−0.11 (0.10)
Education	−0.11 (0.06)	−0.03 (0.02)	0.04 (0.07)	−0.02 (0.04)
High cost	−0.13 (0.17)	−0.05 (0.06)	−0.12 (0.17)	−0.11 (0.09)
Environmental benefits	0.15*** (0.05)	0.05*** (0.02)	−0.77 (0.05)	0.005 (0.025)
ρ^{f}		−0.99 (0.11)		

Fit Statistics	
Log likelihood	−279.61
Percent correctly predicted	92%
Akaike's Information Criterion (AIC)	2.14
Number of observations	301

[a] The bivariate probit selection model used follows the econometric procedures outlined in Khanna (2001).
[b] Standard errors are asymptotic.
[c] Marginal effects for the single decision to adopt cover crops were calculated following Greene (2003) estimated using a univariate probit model at the means of the explanatory variables. Asymptotic standard errors estimated using the delta method (Greene, 2003) are in parentheses.
[d] Marginal effects for the conditional probability of a perceived yield increase, given cover crop adoption were calculated following Greene (2003) at the means of the explanatory variables. These marginal effects include both direct and indirect effects. Asymptotic standard errors estimated using the delta method (Greene, 2003) are in parentheses.
* Indicates statistical significance at $p = 0.10$ level, ** at $p = 0.05$ level, and *** at $p = 0.01$ level.

Table 4. Estimation Results for the Heteroskedastic Tobit Regression Model of Perceived Yield Gain from Using a Cover Crop

	Parameters		Marginal Effects	
Variable	Estimate	Standard Error[a]	Estimate[b]	Standard Error[c]
		Conditional Mean		
Intercept	21.00***	3.50	—	—
No rotation	15.55***	2.51	15.13***	2.44
Peanuts	−8.40***	1.38	−8.18***	1.35
Corn	0.01	0.50	0.01	0.49
Cotton	13.76**	5.63	13.38**	5.47
Soybean	0.68	1.50	0.66	1.46
Experience	−0.18***	0.06	−0.17***	0.06
Plan	−0.48	5.62	−0.47	5.47
Cost share	−2.17***	0.70	−2.11***	0.68
Irrigation	4.90***	0.68	4.77***	0.66
Intensity	0.08	0.49	0.08	0.48
Conservation tillage	−3.16***	0.84	−3.07***	0.82
Legume	3.74	6.71	3.64	6.53
Credit N	5.28***	1.14	5.14***	1.11
Apply N	4.92***	0.90	4.78***	0.87
Timing	−1.89***	0.24	−1.84***	0.23
Bale or graze	−3.32***	0.87	−3.22***	0.85
Max biomass	−3.09***	1.06	−3.01***	1.03
Education	−0.61***	0.172	−0.59***	0.17
$\lambda_{D,i}$	3.82***	1.32	—	—
$\lambda_{A,i}$	−6.28***	1.80	—	—
		Conditional Variance		
Farm size	−3.48***	0.15	−1.07***	0.05
Percent rent	6.52***	0.44	2.00***	0.13
Experience	0.16***	0.01	0.05***	0.004
Program	−5.30***	0.33	−1.62***	0.10
Off-farm income	2.75***	0.28	0.84***	0.09
High cost	−0.12	0.27	−0.04	0.08
Environmental benefits	−0.14	0.10	−0.04	0.03
		Fit Statistics		
Log likelihood		−173.38		
Akaike's Information Criterion (AIC)		5.54		
Number of observations		73		

[a] Standard errors are asymptotic.
[b] Marginal effects were calculated at the mean value of the explanatory variables following procedures in Greene (2003, 2007). Changes in the explanatory variables used to estimate the conditional variance (to correct for heteroskedasticity) will affect the conditional mean, thus the presence of marginal effect estimates for these variables. The marginal effect estimates are useful for inferring the marginal effects of unit changes in the explanatory variables for the subpopulation used to estimate the model. For generalization to the entire population (of farmers in Alabama who have adopted cover crops and perceived a yield gain), the parameter estimates of the conditional mean should be utilized (Greene, 2003, 2007).
[c] Standard errors are asymptotic and estimated using the delta method (Greene, 2003).
* Indicates statistical significance at $p = 0.10$ level, ** at $p = 0.05$ level, and *** at $p = 0.01$.

their crops are more likely to adopt cover crops (by as much as 16%), as the potential drawbacks from their use, such as decreased soil moisture in drier climatic conditions at cash crop planting, may be avoided. Furthermore, the number of perceived environmental benefits was another significant factor increasing the likelihood of adopting cover crops by 5% for each additional benefit perceived. Thus, environmentally conscious farmers may be more likely to adopt.

Stage Two – Perceived Yield Benefit of Cover Crops by Adopters

The second stage of the model can be thought of as a conditional probit regression (type) model, conditioned on the fact that the farmer has already adopted cover crops. This viewpoint allows one to interpret the marginal effects in Table 3 for the Perceived Yield Benefits Equation. These marginal effects indicate the likelihood a factor would increase the probability a farmer who has adopted cover crops would perceive a positive yield benefit from using a cover crop. Given the use of the bivariate probit model, the marginal effects capture both direct effects from the conditional probability of perceiving a yield benefit and indirect effects from the probability of adopting cover crops.

The results in Table 3 indicate that growing soybeans (soybean; 0.37; $p = 0.038$) and maximizing cover crop biomass (max biomass; 0.34; $p = 0.035$) have a significantly positive and direct effect on the likelihood a farmer will perceive a positive yield benefit for their cash crop from use of a cover crop. Given soybeans are a legume, soils on which a crop rotation incorporating soybeans is planted may have higher nitrogen content, providing subsequent crops and cover crops needed nitrogen for growth. This may reduce the immediate cost of planting and managing the cover crop, especially if a goal is to maximize cover crop biomass (Snapp et al., 2005). Farmers were 21% more likely to perceive a yield benefit if soybean was in the crop rotation. Maximizing biomass may help optimize soil and crop productivity (Morton, Bergtold, and Price, 2006), as well as reduce weed pressures (Reddy, 2003), thereby improving the perceived yield benefit from a cover crop. Farmers were 19% more likely to perceive a yield benefit for the cash crop if a management goal was to maximize cover crop biomass.

Stage Three – Perceived Yield Benefit from Cover Crops by Adopters

The third stage of the model can be thought of as a heteroskedastic tobit regression conditional on a farmer choosing to adopt and perceiving a positive yield benefit after adoption. The objective of the third stage was to examine the factors that impacted farmers' perceived magnitude of a cash crop yield gain from using a cover crop. Results of this model are reported in Table 4. The marginal effects presented in Table 4 represent the marginal change in the level of the perceived yield benefit given a change in the level of an explanatory variable for the subpopulation used to estimate the regression model. To generalize to the population of farmers targeted by the survey in Alabama, the coefficient estimates should be used instead to examine marginal changes in the level of perceived yield benefit (Greene, 2003). While the focus will be on the coefficient estimates, marginal effect estimates are provided for completeness.

A number of the farm characteristics and cover crop management practices significantly impacted the level of positive perceived yield benefit by adopters. Statistically significant factors included having no rotation (no rotation; 15.55; $p = 0.0001$); growing peanuts (peanuts; −8.40; $p < 0.000$); growing cotton (cotton; 13.76; $p = 0.015$); years of farm experience (experience; −0.18; $p = 0.003$); receipt of cost share payments (cost share; −2.17; $p = 0.002$); use of irrigation (irrigation; 4.90; $p < 0.000$); use of conservation tillage (conservation tillage; −3.16; $p = 0.0002$); crediting the nitrogen supplied by a legume cover crop (credit N; 5.28; $p < 0.000$); application of fertilizer to the cover crop (apply N; 4.92; $p < 0.000$); cover crop termination timing (timing; −1.89; $p < 0.000$); baling or grazing of cover crop biomass (bale or graze; −3.32; $p = 0.0001$); managing to maximize cover crop biomass (max biomass; −3.09; p = 0.004); and level of education (education; −0.61; p = 0.0004). Given the potential advantages of crop rotations, having no rotation may increase the yield gain from using a cover crop . Cotton is one of the primary cash crops grown in the state of Alabama. Thus, it is expected that farmers would have the most experience with cover crops when growing them in rotations with this cash crop. The negative impact on the perceived yield benefit when growing peanuts may be due to the fact that soil can be significantly disturbed when harvesting peanuts and use of conservation tillage with this cash crop is significantly less than with corn, cotton, and soybeans in the state (Conservation Technology Information Center, 2004).

Farm experience had a negative impact on the perceived benefit from using cover crops. Farmers' perceptions may be tempered with more experience, making them more critical in determining cover crop benefits due to past conservation experience and more conservative due to potential uncertainty. Farmers with more experience may have higher skill specialization, increasing the opportunity cost of changing enterprises (Abadi Ghadim and Pannell, 1999). Along the same lines, education had a negative impact on the perceived yield benefit from using cover crops as well. Having cost share assistance for planting a cover crop reduced the perceived yield benefit from the cover crop. Only a third of the farmers who received cost share assistance to plant a cover crop perceived a yield benefit for the following cash crop.

Cover crops can result in better soil water infiltration and improve soil moisture, but may deplete available water in the soil needed for planting and emergence of the following cash crop (Unger and Vigil, 1998). The use of irrigation may provide needed water during the establishment of the following cash crop, providing a potential explanation for the positive impact the use of irrigation had on the perceived yield benefit from the cover crop. Conservation tillage had a negative effect on the perceived yield benefit. Twenty-three percent of the farmers who perceived a yield benefit used more conventional tillage methods and experienced a higher yield benefit from the use of a cover crop, likely as a green manure. Incorporation of cover crop residues in the soil as a green manure with recommended applications of N fertilizer to the cash crop have been shown to increase crop yields (e.g., Bauer, Camberato, and Roach, 1993).

Larson et al. (1998) show that risk-averse farmers would be likely to adopt legume cover crops, but are not likely to reduce the amount of N applied to the cash crop. Farmers exhibiting this type of behavior did not likely experience an increase in the perceived yield from the use of a legume cover crop. Farmers that credited the N provided by the legume to the following cash crop by reducing N fertilizer rates perceived a yield benefit of 5.28%. Application of N fertilizer to the cover crop to increase the level of biomass resulted in an increase in the perceived yield benefit of 4.92%. Residual N from fertilizer applied to the cover crop may increase cash crop yields and additional biomass may further improve soil productivity further increasing cash crop yield potential, making application of N to the cover crop a management practice that may increase the perceived yield benefits (Balkcom et al., 2008 and Reiter et al., 2008). Both timing of cover crop termination, as well as baling or grazing of cover crop biomass, resulted in a decrease in the perceived yield benefit of the cover crop. Termination of the cover crop closer to the planting of the cash crop may reduce soil moisture and nutrient availability needed to establish the following cash crop, affecting yield potential (Snapp et al., 2005). While a cover crop that is baled or grazed may result in a perceived yield benefit, the level of the perceived yield benefit is likely to be lower than with cover crops used strictly for conservation purposes, as biomass levels are greatly reduced, decreasing protection for the soil and potentially lowering soil productivity.

Maximizing cover crop biomass increases the amount of residue left on the soil surface and in turn may improve the performance of the cover crop (Morton, Bergtold, and Price, 2006). Respondents who adopted cover crops and managed them following this principle actually perceived a lower yield benefit to their cash crop from the cover crop. This result could be due to a lack of necessary equipment to properly plant into heavy cover crop residues; baling or grazing of cover crop residues; or problems with cash crop establishment (e.g., slow soil warming) (Saini, 2009; Snapp et al., 2005).

Conclusions

Understanding the perceived benefits of using winter cover crops and the factors that shape these perceptions can provide insight into the decision making process farmers utilize in deciding to adopt and/or retain the use of cover crops on their farm. A three-stage model of cover crop adoption and perceived yield gain was developed to examine the adoption of cover crops by farmers and the perceived impact on farm productivity in terms of perceived gains in cash crop yield by adopters. The first stage provides guidance concerning the factors influencing the adoption of cover crops by farmers in Alabama. The second stage provides guidance on factors that affect if adopters have a positive perceived yield benefit from using cover crops (i.e., in a way, a positive experience). The third stage then examines the management factors that impact the magnitude of the perceived yield gain. Results suggest that re-educating farmers concerning the environmental impacts of cover crops on-site and off-site may improve the likelihood of farmers adopting this conservation practice. Furthermore, working with farmers to help educate landlords may help alleviate any apprehension a farmer may have about adopting this practice on rented lands. This could be relatively significant, given on average 60% of a farmer's land in our sample was rented.

The second and third stages of the model examine the perceptions of farmers who have already adopted cover crops. It is assumed that farmers' perceptions concerning the yield benefits from adopting cover crops are a significant factor in determining the continued use of this practice on-farm. Model results in the second stage further suggest that outreach efforts should try to get farmers to include cover crops in their conservation plans. Furthermore, efforts should address advantageous crop rotations, such as incorporation of leguminous cash crops.

Model results in the third stage suggest strongly that proper management of cover crops will have a significant impact on the magnitude of the perceived yield benefit. Farmers adopting cover crops need to understand the site specific advantages and disadvantages, as well as the management practices that will make the cover crop a profitable practice in the production system. Results suggest that using legume cover crops as an alternative nitrogen source; applying nitrogen to the cover crop when applicable; terminating the cover crop at the right time; and considering to what extent a cover crop should be baled or grazed will improve the viability of adding a cover crop in rotation. Given that more experience with cover crop adoption has occurred in crop rotations with corn and/or cotton, this may be a starting point for getting farmers new to the practice more experienced, building positive perceptions, and increasing adoption and retention. Another strategy for promoting the adoption and continued use of cover crops would be to target farmers using conservation tillage. Cover crops may be viewed as a more intensive residue management practice, and prior use of conservation tillage on-farm may prepare a farmer for managing higher levels of residue or biomass on the surface of their fields. Cover crops increase management intensity on-farm and prior experience with a conservation tillage system may prepare the farmer to intensify on-farm conservation efforts (Balkcom et al., 2007).

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