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

Jason S. Bergtold[1], Patricia A. Duffy[2], Diane Hite[2] and Randy L. Raper[3]

[1] Assistant Professor, Department of Agricultural Economics, Kansas State University, 304F Waters Hall, Manhattan, KS 66506-4011, Email: Bergtold@ksu.edu (Corresponding Author)

[2] Professor and Professor, Department of Agricultural Economics and Rural Sociology, Auburn University, Auburn, AL.

[3] Agricultural Engineer, National Soil Dynamics Laboratory, Agricultural Research Service, USDA, Auburn AL.

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Abstract

The inclusion of cover crops in cropping systems brings both direct and indirect costs and benefits. Farmers will adopt and continue to utilize cover crops in their production systems as long as the perceived benefit of using cover crops (e.g. increased yield, higher profits, and improved soil productivity) is positive. The perceived benefits, while partially based on actual changes, may be influenced by demographic, economic and management factors. The purpose of this paper is to examine the demographic and management factors affecting the perceived benefit, in terms of improved crop yield, of using winter annual cover crops. A tobit model is estimated using survey data of Alabama farmers examining cover crop use and management. The model examines the potential effect of different agronomic, demographic and management factors on the perceived yield gain from using winter cover crops of Alabama row crop producers. Estimation results indicated that growing peanuts, growing soybeans, high debt, high gross farm sales, use of conservation tillage, increased application of N to the cash crop after a legume cover crop, and applying N to the cover crop had a positive and statistically significant impact on farmers' perceived yield gain from using a cover crop. In contrast, number of years farming, farm size, and high cover crop costs had a negative and statistically significant impact on farmers' perceived yield gain from using a cover crop. 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 make in deciding to adopt and/or retain the use of cover crops on their farm.

Keywords: Cover Crops, Conservation, Adoption Process, Tobit Model, Value of Information, Farmer

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Introduction

The inclusion of cover crops in cropping systems brings both direct and indirect costs and benefits. Cover crops can help alleviate drought stress by increasing infiltration rates and soil moisture content; improve soil quality by helping to relieve soil compaction, improve soil organic matter and reduce 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 N mineralization (Snapp et al., 2005). All of these elements have the potential to increase or decrease yields and therefore the profitability of cropping enterprises.

The primary economic benefits of using cover crops are a potential yield benefit and reduced production risk (Jaenicke et al., 2003; Larson et al., 2001; Roberts et al., 1998). These benefits are dependent upon how the cover crop is managed. For example, Morton and Bergtold (2005) provide some preliminary findings that maximizing cover crop biomass production is a key management consideration in optimizing the economic benefit of winter cover crops for the preceding 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 utilize winter cover crops in their production systems as long as the perceived benefit of using cover crops (e.g. increased yield, higher profits, and improved soil productivity) is positive. The perceived benefits, while partially based on actual changes, may be influenced by demographic, economic and management factors, which in turn will impact the adoption of cover crops by farmers.

Pannell (1999) outlines the states of farmer awareness that must be achieved for widespread adoption of an agricultural innovation. These are (i) awareness of the innovation; (ii) perception that the innovation is feasible and worthwhile to trial; and (iii) perception that the innovation promotes farmer's objectives. Pannell conjectures that phase (ii) is probably the most important phase, because trials provide skills and experience about the value of the innovation that will determine its final adoption. In addition, this experience will help the farmer assess the worthiness of the innovation in meeting the farmer's own objectives. Thus, the perceived benefits from utilizing cover crops that will most likely influence the adoption of this conservation practice are going to be significantly shaped through trial and experimentation by farmers. Determining the factors that affect farmers' perceptions during the trial 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 in order to meet societal goals.

The purpose of this paper is to examine the demographic and management factors affecting the perceived benefit, in terms of improved crop yield, of using winter annual cover crops. A tobit model is estimated using survey data of Alabama farmers examining cover crop use and management. The model examines the potential effect of different agronomic, demographic and management factors on the perceived yield gain from using winter cover crops of Alabama row crop producers. It is this perceived yield gain, the authors contend, that is a significant factor in determining the adoption and continued use of winter annual cover crops in the Southeast.

Research Methods and Data

Conceptual Framework

The conceptual framework adopted here follows the work by Abadi Ghadim and Pannell (1999). Their approach is able to account for a myriad of factors, such as learning, dynamics, uncertainty, risk attitudes, demographics and social factors that have been identified in the adoption literature as important social and economic indicators of agricultural innovation adoption.

Consider a farmer who has the option of planting cover crops preceding their cash crop.[1] Assume that the farmers' land is heterogeneous, differing due to soil structure, soil productivity, topography and pest pressures. The primary economic benefit of cover crops is the boost in cash crop yields (Lu et al., 2000), which will vary based on soil and environmental conditions. Let $A_{v,t}^{c}$ represent the amount of land planted under cash crop c with cover crop v in year t; $A_{n,t}^{c}$ represent the amount of land planted under cash crop c with no cover crop in year t; $A_{T,t}^{c}$ represent the total acres devoted to crop c in year t; $G_{v,t}^{C}$ represent the gross margin of an acre of crop c with cover crop v in year t; and $G_{n,t}^{c}$ represent the gross margin of an acre of crop c with no cover crop in year t. Then following Abadi Ghadim and Pannell (1999), the farmer's objective is to maximize profit over time for crop c, i.e.:

$$\max \Pi^{c} = NPV_{t=1}^{n}\left[\int_{0}^{A_{v,t}^{c}} G_{v,t}^{c} dx + \int_{A_{v,t}^{c}}^{A_{T,t}^{c}} G_{n,t}^{c} dx\right] \quad (1)$$

where NPV is the net present value of time period 1 to n.[2]

For a given value of $A_{i,t}^{c}$ for $i = v$ or n, the mean gross margin for producing crop c with or without a cover crop can be calculated over the area planted in time period t, denoted $\bar{G}_{v,t}^{C}$ and $\bar{G}_{n,t}^{c}$, respectively. Furthermore, potential uncertainty due to factors, such as climate and cover crop performance are likely to cause mean gross margins to vary, but it is assumed that the farmer can subjectively determine a probability distribution for each. Thus, the farmer's objective is now to maximize expected profit, i.e.:

[1] For simplicity, it is assumed that farmers only grow one primary cash crop.
[2] Fixed costs are not included in the analysis due to data limitations, but are likely to affect profitability of cover crop usage. For example, the need to buy new equipment, such as a roller/crimper may affect the adoption decision.

$$\max \Pi^c = NPV_{t=1}^{n}\left[E(\bar{G}_{v,t}^{c})A_{v,t}^{c} + E(\bar{G}_{n,t}^{c})A_{n,t}^{c}\right], \qquad (2)$$

where the expectation is over uncertain states of nature (following Abadi Ghadim and Pannell, 1990). Let $A_{v,t}^{c,*}$ represent the optimal solution to the optimization problem given by (2), assuming the farmer decides to plant a cover crop in years 1 to $\bar{t}$ for $\bar{t} < n$.

Now consider the case where a farmer has not planted a cover crop from year 1 to $\bar{t}$. Then profit is equal to:

$$\Pi_0^c = NPV_{t=1}^{\bar{t}}\left[E(\bar{G}_{n,t}^{c})A_{T,t}^{c}\right] + NPV_{t=\bar{t}+1}^{n}\left[E(\bar{G}_{v,t}^{c})A_{v,t}^{c} + E(\bar{G}_{n,t}^{c})A_{n,t}^{c}\right]. \qquad (3)$$

Let $A_{v,t}^{c,**}$ represent the optimal solution to optimization problem given by (2) assuming the farmer decided not to plant a cover crop in years 1 to $\bar{t}$. Given $A_{n,t}^{c} = A_{T,t}^{c} - A_{v,t}^{c}$ and letting $\Delta_{A,t}^{c} = A_{T,t}^{c,*} - A_{v,t}^{c,**}$, then a farmer will plant a cover crop in years 1 to $\bar{t}$ if:

$$\begin{aligned}\Pi^c - \Pi_0^c = {} & NPV_{t=1}^{\bar{t}}\left[E\left(\bar{G}_{v,t}^{c,*} - \bar{G}_{n,t}^{c}\right)A_{v,t}^{c,*}\right] + \\ & NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{G}_{v,t}^{c,*} - \bar{G}_{v,t}^{c,**}\right)A_{v,t}^{c,**} + E\left(\bar{G}_{v,t}^{c,*} - \bar{G}_{n,t}^{c}\right)\Delta_{A,t}^{c}\right] = \\ & NPV_{t=1}^{\bar{t}}\left[E\left(\bar{G}_{v,t}^{c,*} - \bar{G}_{n,t}^{c}\right)A_{v,t}^{c,*}\right] + I_{S+D} > 0, \qquad (4)\end{aligned}$$

where $\bar{G}_{v,t}^{c,*}$ and $\bar{G}_{v,t}^{c,**}$ are the mean gross margins calculated at $A_{T,t}^{c,*}$ and $A_{v,t}^{c,**}$, respectively. The first term after the last inequality in condition (4) represents the value of using or trialing cover crop *v* in years 1 to $\bar{t}$. The second term I_{S+D} represents the value of gained experience, skills, management, and performance expectations of using cover crops in years 1 to $\bar{t}$ on the future performance of cash crop *c* with cover crop *v* in years $\bar{t}$ to *n*. The first component of I_{S+D} represents the expected gain in profit on the area that would have been planted with cover crop *v* in future years without the cover crop being planted in years 1 to $\bar{t}$, $E\left(\bar{G}_{v,t}^{c,*} - \bar{G}_{v,t}^{c,**}\right)A_{v,t}^{c,**}$, while the second component represents the expected increase in profitability from the increase in the amount of land planted to cover crop *v* from years $\bar{t}$ to *n* as a result of using a cover crop in years 1 to $\bar{t}$,

$E(\bar{G}_{v,t}^{c,*} - \bar{G}_{n,t}^{c})\Delta_{A,t}^{c}$. Thus, equation (4) indicates whether or not the value of producing a cover crop in time periods 1 to $\bar{t}$ plus the value of the information it provides, is greater than the opportunity cost of doing so (Abadi Ghadim and Pannell, 1999). These first few years can be thought of as transition years, trial period or prior experience in the growing of cover crops.

Given that crop profitability is dependent upon a myriad of factors (e.g. whole farm dynamics, crop yields, input usage, agronomic factors, etc.) isolating the direct monetary benefit of cover crops by a farmer may be difficult. A suitable proxy may be crop yield, which captures some of the agronomic and economic benefit, but should not be recognized as a direct substitute (i.e. maximizing yield is not synonymous with maximizing profit). Lu et al. (2000) recognize that while cover crops can reduce input costs for the cash crop it is not enough to offset the increased expense from planting the cover crop. Crop yields must be enhanced by the use of a cover crop to derive an economic benefit from them.

To incorporate yield into the model, consider the decomposition:

$$E(\bar{G}_{v,t}^{c,*} - \bar{G}_{n,t}^{c}) = E(\bar{Y}_{v,t}^{c,*} - \bar{C}_{v,t}^{c,*}), \tag{5}$$

where $\bar{Y}_{v,t}^{c,*}$ is the expected revenue gain per acre from increases in yield for cash crop *c* using cover crop *v*. and $\bar{C}_{v,t}^{c,*}$ is the net change in costs per acre (e.g. implementation costs minus cost savings) from using cover crop *v*. This implies that

$$E(\bar{G}_{v,t}^{c,*} - \bar{G}_{v,t}^{c,**}) = E(\bar{Y}_{v,t}^{c,*} - \bar{Y}_{v,t}^{c,**}), \tag{6}$$

where $\bar{Y}_{v,t}^{c,**}$ is the expected revenue per acre gain from increases in cash crop *c* yield from future use of cover crop *v* without adoption in periods 1 to $\bar{t}$. Plugging relationships (5) and (6) into (4) gives:

$$\Pi^{c} - \Pi_{0}^{c} = NPV_{t=1}^{\bar{t}}\left[E(\bar{Y}_{v,t}^{c,*} - \bar{C}_{v,t}^{c,*})A_{v,t}^{c,*}\right] +$$

$$NPV_{t=\bar{t}+1}^{n}\left[E(\bar{Y}_{v,t}^{c,*} - \bar{Y}_{v,t}^{c,**})A_{v,t}^{c,**} + E(\bar{Y}_{v,t}^{c,*} - \bar{C}_{v,t}^{c,*})\Delta_{A,t}^{c}\right] =$$

$$NPV_{t=1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,*}-\bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,*}\right]-NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,**}-\bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,**}\right]. \quad (7)$$

Thus, the difference in profit from choosing to plant in time period 1 to $\bar{t}$ is equal to the value of using cover crop *v* over the entire time horizon minus the potential value of using cover crop *v* under the same management regime in the future, but without the additional skills, experience gained from using cover crop *v* in time period 1 to $\bar{t}$. That is, the second term, $NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,**}-\bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,**}\right]$ represents the opportunity cost of not investing our time into obtaining the skills and experience from using cover crop *v* in time period1 to $\bar{t}$.

It will be helpful to rewrite equation (7) as:

$$\Pi^{c}-\Pi_{0}^{c}= NPV_{t=1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,*}\right)A_{v,t}^{c,*}\right]- NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,**}\right)A_{v,t}^{c,**}\right]-$$
$$NPV_{t=1}^{n}\left[E\left(\bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,*}\right]+ NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,**}\right]=$$
$$R\left(\bar{Y}_{v,t}^{c,*},\bar{Y}_{v,t}^{c,**},A_{v,t}^{c,*},A_{v,t}^{c,**}\right)-C\left(\bar{C}_{v,t}^{c,*},A_{v,t}^{c,*},A_{v,t}^{c,**}\right), \quad (8)$$

where *R*(.) is the expected gain in revenue generated in time period 1 to $\bar{t}$ using cover crop *v* plus the future revenue generated from the additional skills, experience and performance expectations from using cover crops during that time period, and *C*(.) is the expected net change in costs from the same process.

The question of interest in this study is what factors affect the perceived benefit of cover crops by farmers. The factors that affect the perceived or expected value of using a cover crop by the farmer include: (i) factors affecting the profitability of cash crop production, including cash and cover crop management, farm characteristics, risk attitudes and market conditions; and (ii) factors affecting skills development, experience and performance expectations, including experience with other conservation practices, education, age, and perceptions concerning the environment and cover crop management.

Assume that:

$$R\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) - C\left(\bar{C}_{v,t}^{c,*}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = f\left(\boldsymbol{X^f}, \boldsymbol{X^p}, \boldsymbol{X^d}, \boldsymbol{X^e}\right), \text{ or}$$

$$R\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = f\left(\boldsymbol{X^f}, \boldsymbol{X^p}, \boldsymbol{X^d}, \boldsymbol{X^e}\right) + C\left(\bar{C}_{v,t}^{c,*}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right), \text{or}$$

$$R\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = f\left(\boldsymbol{X^f}, \boldsymbol{X^p}, \boldsymbol{X^d}, \boldsymbol{X^e}\right) + \boldsymbol{C} \tag{9}$$

where $\boldsymbol{X^f}$ is a (K_f x 1) vector of farm characteristic variables (e.g. farm size, farm sales, cash crop choice,), $\boldsymbol{X^p}$ is a (K_p x 1) vector of farm/management practice variables (e.g. use of conservation tillage, cover crop management characteristics, use of irrigation), $\boldsymbol{X^d}$ is a (K_d x 1) vector of demographic variables (e.g. years farming, financial disposition, education), $\boldsymbol{X^e}$ is a (K_e x 1) vector of variables capturing farmers' perceptions about cover crops (e.g. environmental benefits, perceived cost), and $\boldsymbol{C}$ is a cost variable representing the relative net cost of cover crop *v*. These factors play a part in determining both the gain in expected profit from using a cover crop in years 1 to $\bar{t}$ and the value of the experience, skills and performance knowledge gained from using cover crops for that time period (Abadi Ghadim and Pannell, 1999; Luzar and Diagne, 1999; Nowak, 1992; Rahm and Huffman, 1984; Uri, 1999).

Assuming that farmers are price takers and that prices are constant over the time horizon, then for an individual farmer $R\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right)$ is relative to the expected or perceived change in the yield of cash crop *c* in time period 1 to $\bar{t}$ using cover crop *v* plus the additional yield generated from the skills, experience and performance expectations acquired from using cover crops during that time period. That is, $R\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = \frac{1}{p_c}\tilde{R}\left(\bar{y}_{v,t}^{c,*}, \bar{y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right)$, where p_c represents the price of cash crop *c* and $\bar{y}_{v,t}^{c}$ represents the mean change in cash crop *c* yield from using cover crop *v* over the total area planted using cover crop *v* (e.g. $A_{v,t}^{c}$). Plugging this relationship into equation (9), gives:

$$\tilde{R}\left(\bar{y}_{v,t}^{c,*}, \bar{y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = p_c[f\left(\boldsymbol{X^f}, \boldsymbol{X^p}, \boldsymbol{X^d}, \boldsymbol{X^e}\right) + \boldsymbol{C}]. \tag{10}$$

Now assume that $f\left(\boldsymbol{X^f}, \boldsymbol{X^p}, \boldsymbol{X^d}, \boldsymbol{X^e}\right) = \overline{\boldsymbol{\alpha}}'\boldsymbol{X^f} + \overline{\boldsymbol{\beta}}'\boldsymbol{X^p} + \overline{\boldsymbol{\gamma}}'\boldsymbol{X^d} + \overline{\boldsymbol{\delta}}'\boldsymbol{X^e}$**,** then substituting into (10) gives:

$$\tilde{R}\left(\bar{Y}_{v,t}^{c,*}, \bar{Y}_{v,t}^{c,**}, A_{v,t}^{c,*}, A_{v,t}^{c,**}\right) = p_c[\overline{\boldsymbol{\alpha}}'\boldsymbol{X^f} + \overline{\boldsymbol{\beta}}'\boldsymbol{X^p} + \overline{\boldsymbol{\gamma}}'\boldsymbol{X^d} + \overline{\boldsymbol{\delta}}'\boldsymbol{X^e} + \boldsymbol{C}]$$

$$= \boldsymbol{\alpha}'\boldsymbol{X^f} + \boldsymbol{\beta}'\boldsymbol{X^p} + \boldsymbol{\gamma}'\boldsymbol{X^d} + \boldsymbol{\delta}'\boldsymbol{X^e} + \boldsymbol{\theta}\boldsymbol{C}, \quad (11)$$

where $\boldsymbol{\theta} = \left(\frac{\mathbf{1}}{\boldsymbol{p_c}}\right)$ and all the other parameter vectors are multiplied by ($1/p_c$) (e.g. $\overline{\boldsymbol{\alpha}} = \frac{\boldsymbol{\alpha}}{\boldsymbol{p_c}}$).

Data

Data for the analysis was obtained from a mail survey developed by Auburn University and USDA, Agricultural Research Service and administered by the USDA, National Agricultural Statistics Service, Alabama State Office to Alabama row crop producers about cover crop adoption, experience and management. 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 Agricultual Census Data, which amounted to 1312 farmers across the state. The sample populations represented the entire set of farmers meeting the specified conditions in the state of Alabama. The survey was administered by mail to 1162 farmers. The mailing included the survey, 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 one week after this mailing with the opportunity to do the survey over the phone. The remaining 150 surveys were delivered (to be mailed back) and administered (if requested) by field enumerators. The number of completed surveys was 362, of that, 345 were usable, giving a response rate of 28%. Comparing summary statistics using 2002 census data of

Table 1: Comparing Summary Statistics for Survey Respondents and Sample Population Using 2002 Agricultural Census Data

Variable	**Survey Respondents** (*n = 362*)	**Sample Population** (*n = 1312*)
Age	55.7	58.1
Gross Value of Farm Sales		
(as percent of sample size)		
< $50,000	10.5[a]	N/A
$50,000 to $99,999	19.5	10.2
$100,000 to $249,999	29.0	32.7
$250,000 to $499,999	21.3	25.8
$500,000 to $999,999	11.7	19.9
➢ $1,000,000	8.1	11.5
Ethnicity		
(as percent of sample size)		
White or Caucasian	98.2	96.4
Black or African American	0.9	1.7
American Indian	0.9	0.9
Other	0.0	1.0
Row Crop Acreage	753	878

Source: 2002 Agricultural Census, USDA-NASS

[a] 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.

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 used in the econometric model specified in the next sub-section of the paper are presented in Table 2.

Data for the dependent variable, $E(\Delta Y)$, the perceived yield gain from using cover crop v preceding cash crop c was obtained from a question on the survey asking farmers using cover crops if they experienced an increase in cash crop yield. If they answered yes, then they were asked what crops experienced an increase in yield and by how much (as a percent). If they answered no, it was assumed that the farmer experienced a decrease or experienced no change in

Table 2: Variable Definitions and Summary Statistics

Variable	Description	Mean (Frequency[a])	Standard Deviation
	Dependent Variable		
$E(\Delta Y)$	Perceived gain in yield as a percentage from using cover crop v preceding cash crop c (censored at 0)	8.8	11.4
	Farm Characteristics		
Peanuts	Equal to '1' if peanuts grown and a cover crop increased perceived yield, '0' otherwise.	0.14	---
Corn	Equal to '1' if corn grown and a cover crop increased perceived yield, '0' otherwise.	0.10	---
Soybean	Equal to '1' if soybean grown and a cover crop increased perceived yield, '0' otherwise.	0.07	---
Other Grains	Equal to '1' if other grains grown and a cover crop increased perceived yield, '0' otherwise.	0.01	---
Farm Size	Total acres owned plus rented	1249.7	1135.1
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 – 0.06 2 – 0.17 3 – 0.30 4 – 0.23 5 – 0.13 6 – 0.11	---
Percent Row Crop	Percent of gross farm sales from row crop production.	72.1	30.4
Experience	Number of years farming.	30.0	11.6
	Farm and Conservation Practices		
Irrigation	Equal to '1' if cash crop is irrigated, '0' otherwise.	0.27	---
Conservation Tillage	Equal to '1' if use conservation tillage methods, '0' otherwise.	0.74	---
Legume	Equal to '1' if a legume cover crop is planted, '0' otherwise	0.08	---
N + Legume	Equal to '1' if a legume is planted and additional N is applied to the cover crop, '0' otherwise.	0.14	---
Apply N	Equal to '1' if N is applied to cover crop, '0' otherwise.	0.55	---
Timing	Equal to '1' if terminate cover crop 1 week 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 – 0.12 2 – 0.37 3 – 0.30 4 – 0.21	---
Bale or Graze	Equal to '1' if harvest cover crop residues or allow cattle to graze on cover crop residues, '0' otherwise.	0.39	---
Max Biomass	Equal to 1' if manage cover crop to maximize biomass production, '0' otherwise.	0.53	---

Table 1: continued.

Variable	Description	Mean (Frequency[a])	Standard Deviation
	Demographics		
Off-Farm Income	Equal to '1' if any family members bring in off-farm income, '0' otherwise.	0.52	---
High Debt	Equal to '1' if debt level is considered high by the farmer, '0' otherwise.	0.15	---
No Diploma	Equal to '1' if do not have a high school diploma, '0' otherwise.	0.03	---
College	Equal to '1' if completed college or higher degree, '0' otherwise	0.32	---
Education	Level of education. Equal to '1' if some high school, '2' with diploma or GED, '3' if trade school, '4' if some college, '5' if college graduate, '6' if postgraduate.	1 – 0.02 2 – 0.37 3 – 0.02 4 – 0.27 5 – 0.29 6 – 0.03	---
	Farmer Perceptions		
High Cost	Equal to '1' if the farmer perceives cover crops as being a high cost conservation practice, '0' otherwise.	0.52	---
Environmental Benefits[b]	An ordinal variable indicating the number of environmental benefits the farmer perceives that cover crops provide.	4.2	1.8

[a] For discrete data frequency of response is reported. For ordinal variables this includes the frequency for each response category.
[b] Environmental benefits include reduced soil erosion, increased water storage, increased soil organic matter, weed suppression, reduced soil compaction and decreased runoff.

cash crop yield. Thus, $E(\Delta Y)$ is censored, in that, it is equal to 0 if a decrease or no change in yield occurred. The $E(\Delta Y)$ is meant to serve as a proxy for $\tilde{R}$, in that the perceived yield gain over time will change as the farmer gains experience and skills. Thus, $E(\Delta Y)$ represents the perceived gain in cash crop c yield in time period $\bar{t}+1$ (and in turn expected value in future periods), given $E(\Delta Y)$ is influenced by a farmer's past history of using cover crops. Taking into account that $E(\Delta Y)$ examines perceptions of farmers' who already use cover crops; that farmer's had the ability to list multiple crops on the survey; and the presence of missing data, there were 185 usable observations across 157 respondents. This represents the number of observations used in the estimation of the econometric model presented in the paper. Farmers' indicated that they planted winter wheat, cereal rye, ryegrass, clover, millet, hairy vetch, oats, triticale, lupine, Austrian winter pea, oats and mixtures of these as cover crops.

The explanatory variables used in the model included: (i) farm characteristics: cash crops grown after the use of a cover crop, farm size, gross farm sales, percent of sales from row crops, years farming; (ii) farm/management practices: binary variables to indicate use of irrigation, conservation tillage, legume cover crop, application of N after a legume to the cash crop, timing of cover crop termination, baling or grazing of cover crop residues and maximization of cover crop biomass production; (iii) demographic variables: binary variables indicating the presence of off-farm income; a high level of debt, no high school diploma, a college degree; and (iv) farmers' perceptions: binary variables indicating if costs of planting a cover crop are high and the number of environmental benefits of using a cover crop indicated on the survey. The high cost binary variable was used to capture the potential effects of $\boldsymbol{C}$ on $\tilde{R}$ or $E(\Delta Y)$.

Farm characteristics are likely to have different affects on the adoption of cover crops as a conservation practice. The choice of cash crop will dictate the judicious selection of a winter cover crop (Dabney et al., 2001; Snapp et al., 2005). For example, planting crimson clover prior to corn can help meet the demand for nitrogen by the proceeding 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 *et al*., 2000; Soule, 2001). Farm size can potentially play a significant factor in the adoption of cover crops (Bergtold et al., 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. Greater farm experience may increase or decrease the expected benefits of a cover crop, due to past experiences with other conservation practices, affect on risk aversion, and improvements in farmers' skills (Abadi Ghadim and Pannell, 1999).

Farming practices and cover crop management will have a significant effect on the performance of the cover crop and in turn I_{S+D}, the skills and experience developed through cover crop experimentation and use. Irrigation will likely be seen as positively beneficial on the perceived benefit of cover crops, as potential concerns about water availability for the cash crop may be avoided (Dabney et al., 2001). Use of conservation tillage is likely to increase the probability of adopting cover crops (Bergtold et al., 2007), and prior experience with conservation tillage practices and the expected benefits may have a positive effect on the perceived gains from a cover crop.

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 et al., 2001). Morton and Bergtold (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 benefit of the cover crop as biomass levels increase. On the other hand, farmers with adverse experiences or limited experiences with cover crops may find high levels of biomass to risky, resulting in a potentially negative relationship. 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 from cover crops. The effect of timing of termination is uncertain, as the interaction between maximizing biomass production, affect of lower soil temperatures due to increased cover, and termination method all affect the performance of the cover crop and proceeding cash crop (Ashford and Reeves, 2003; Snapp et al., 2005)

Use of legumes can provide additional N for the proceeding cash crop, but due to limited availability of that N for some time period, it may not affect optimal N rates for the cash crop (Dabney et al., 2001; Lu et al., 2000). Thus, the net effect of using legume cover crops is likely to be positive, but the need for additional N for the cash crop may lower potential expected benefits of these types of covers.

The impact of demographic factors on the expected performance of cover crops is somewhat unclear. Gould *et al*. (1989) found a negative relationship between the adoption of conservation tillage practices and off-farm income, potentially due to the limited amount of a 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. High levels of debt are likely to make a farmer more risk averse toward adopting cover crops, but the potential yield stabilizing effects on cash crops from their use may increase the farmer's perceived benefit (Snapp et al., 2005). 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 towards 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 cover crops will decrease, by a potentially significant amount. 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.

Econometric Model Specification

The econometric model estimated follows the functional form specified by equation (11) but with $E(\Delta Y)$ as a proxy to $\tilde{R}$, giving:

$$E(\Delta Y_i) = \boldsymbol{\alpha}'\boldsymbol{X}_i^{\boldsymbol{f}} + \boldsymbol{\beta}'\boldsymbol{X}_i^{\boldsymbol{p}} + \boldsymbol{\gamma}'\boldsymbol{X}_i^{\boldsymbol{d}} + \boldsymbol{\delta}'\boldsymbol{X}_i^{\boldsymbol{e}} + \boldsymbol{\theta}\boldsymbol{C}_i + u_i, i \in N \ , \tag{12}$$

where it is initially assumed that $u_i \sim N(0, \sigma^2)$. Given that $E(\Delta Y_i)$ is censored, equation (12) is estimated as a censored regression (tobit) model. In this case, the regression function takes the form:

$$E(\Delta Y_i) = \Phi\left(\frac{\boldsymbol{\alpha}'\boldsymbol{X}_i^{\boldsymbol{f}} + \boldsymbol{\beta}'\boldsymbol{X}_i^{\boldsymbol{p}} + \boldsymbol{\gamma}'\boldsymbol{X}_i^{\boldsymbol{d}} + \boldsymbol{\delta}'\boldsymbol{X}_i^{\boldsymbol{e}} + \boldsymbol{\theta}\boldsymbol{C}_i}{\boldsymbol{\sigma}}\right) \times$$

$$(\boldsymbol{\alpha}'\boldsymbol{X}_i^{\boldsymbol{f}} + \boldsymbol{\beta}'\boldsymbol{X}_i^{\boldsymbol{p}} + \boldsymbol{\gamma}'\boldsymbol{X}_i^{\boldsymbol{d}} + \boldsymbol{\delta}'\boldsymbol{X}_i^{\boldsymbol{e}} + \boldsymbol{\theta}\boldsymbol{C}_i + \sigma\lambda_i) + u_i, i \in N \ , \tag{13}$$

where Φ represents the cumulative density function of the normal distribution,

$$\lambda_i = \frac{\phi\left[\left(\boldsymbol{\alpha}'\boldsymbol{X}_i^{\boldsymbol{f}} + \boldsymbol{\beta}'\boldsymbol{X}_i^{\boldsymbol{p}} + \boldsymbol{\gamma}'\boldsymbol{X}_i^{\boldsymbol{d}} + \boldsymbol{\delta}'\boldsymbol{X}_i^{\boldsymbol{e}} + \boldsymbol{\theta}\boldsymbol{C}_i\right)/\sigma\right]}{\Phi\left[\left(0 - \boldsymbol{\alpha}'\boldsymbol{X}_i^{\boldsymbol{f}} + \boldsymbol{\beta}'\boldsymbol{X}_i^{\boldsymbol{p}} + \boldsymbol{\gamma}'\boldsymbol{X}_i^{\boldsymbol{d}} + \boldsymbol{\delta}'\boldsymbol{X}_i^{\boldsymbol{e}} + \boldsymbol{\theta}\boldsymbol{C}_i\right)/\sigma\right]},$$

and ϕ represents the probability density function of the normal distribution (Greene, 2003).

The dependent variable, $E(\Delta Y_i)$, has repeated observations for some respondents (i.e. some respondents reported gains from cover crops on more than one cash crop on their farm) and exhibits variance heterogeneity across farms (due to farming characteristics and management experience), indicating the presence of heteroskedasticity. To correct for this, the conditional variance is modeled as:

$$\sigma_i^2 = \sigma^2 e^{\boldsymbol{\rho}'\boldsymbol{D} + \boldsymbol{\omega}'\boldsymbol{Z}}, \tag{14}$$

where $\boldsymbol{D}$ is a vector of indicator variables if a farm reports more than one crop (to capture the effect of repeated measures) and $\boldsymbol{Z}$ are proxy variables for farm characteristics (farm size and gross farm sales) and management experience (education level and years farming) (Greene, 2003).

The model was estimated using the PROC QLIM procedure in SAS.

Results and Discussion

Estimation results for the econometric model specified by equations (13) and (14) are provided in Table 3. A pseudo-R^2 was calculated based on the likelihood ratio following Magee (1990), indicating a relatively decent fit to the observed data. While not reported, the dummy variables included in the conditional variance, given by equation (14), were found to be statistically significant, indicating that there is within-farm variation in perceptions about the benefits of alternative cover crop/cash crop combinations. Furthermore, the significance of the explanatory variables in the conditional variance justifies the heteroskedasticity correction adopted to capture heterogeneity across farms.

Of the farm characteristics examined, growing peanuts (18.95; $P<0.000$), growing soybeans (13.25; $P<0.0000$), farm size (-0.34; $P=0.051$), high gross farm sales (3.7; $P=0.004$), and farm experience (-0.26; $P=0.026$) were statistically significant. When growing peanuts, soybeans and cotton, cash crop residue in conservation tillage systems are low and deteriorate quickly in the humid warmer climate of the Southeast. Thus, growing a cover crop that can provide more residue for ground cover can significantly improve the benefits of adopting conservation tillage systems, thereby improving the perceived gain from the cover crop. Farmers may determine that corn provides sufficient ground cover to receive the optimal benefits from a residue management system incorporating this cash crop, indicating why this variable is not

Table 3: Estimation Results for Tobit Model of the Perceived Yield Benefit from Cover Crops

Variable	Parameter Estimate	Standard Error	P-Value for Significance Test [a]
	Conditional Mean		
Intercept	-28.31	8.98	0.002
Peanuts	18.95	3.33	0.000
Corn	2.34	2.68	0.379
Soybean	13.25	3.03	0.000
Other Grains	21.58	19.61	0.271
Farm Size	-0.34	0.17	0.051
Farm Sales	3.70	1.29	0.004
Percent Row Crop	0.11	0.06	0.069
Experience	-0.26	0.12	0.026
Irrigation	1.98	3.39	0.559
Conservation Tillage	5.37	2.63	0.041
Legume	9.00	6.16	0.144
N + Legume	6.88	3.47	0.047
Apply N	6.40	2.49	0.010
Timing	0.75	1.03	0.467
Bale or Graze	0.51	2.31	0.825
Max Biomass	-2.38	2.33	0.307
Off-Farm Income	0.73	2.39	0.760
High Debt	9.27	3.37	0.006
No Diploma	2.20	6.88	0.749
College	-0.98	2.45	0.69
High Cost	-5.37	2.17	0.013
Environmental Benefits	1.10	0.89	0.219
	Conditional Variance[b]		
σ	2.34	2.24	0.296
Education	0.36	0.21	0.085
Experience	0.01	0.02	0.518
Farm Size	-0.03	0.03	0.273
Farm Sales	0.89	0.42	0.032
	Fit Statistics		
Log Likelihood			-402.4
Pseudo R^2			0.77
AIC			916.8
Number of Observations			185

[a] Significance tests were conducted in SAS using PROC QLIM with asymptotic t-tests.
[b] The parameter estimates for the dummy variables representing farms with multiple observations are not reported due to space limitations, but most of the parameters were statistically significant.

statistically significant using a cover crop. The negative effect that increasing farm size has on the perceived yield gain from using a cover crop could be due to a scarcity of resources, such as labor and farm machinery (e.g. roller/crimpers), needed to manage cover crops properly on larger operations, thereby increasing the potential risk faced by a larger operator. Furthermore, larger operations have more land heterogeneity that may result in greater variability of cover crop performance, lowering expectations for the overall farm. Farm sales have a positive impact on the perceived yield gains from incorporating cover crops into the crop production system. Higher farm sales may reflect the positive reaction of successful farmers who have integrated cover crops into their operations, but more likely farm sales reduces the potential risk aversion to using cover crops, thereby increasing their potential value. Furthermore, farm sales had a significant impact on the variation of perceptions across farms, indicating possibly that as farm sales increase expected gains from cover crops become more variable, as these farms are willing to take riskier ventures into adopting alternative cover crop combinations and options (e.g. lupine or mixtures).

An interesting find was that more farm experience had a negative impact on the perceived gain from using cover crops. Farmers' perceptions may be tempered with more experience, making them more critical in determining cover crop benefits. Abadi Ghadim and Pannell (1999) indicate that more farm experience may (i) increase the likelihood of negative experiences with past conservation efforts; (ii) make older farmers more risk averse; (iii) increase skill specialization, increasing the opportunity cost of changing enterprises; (iv) decrease the value of information when reducing uncertainty. It may possibly be the case the wide spread adoption of cover crops will take a generation to occur.

Of the farm and cover crop management practices in the econometric model, use of conservation tillage (5.37, $P=0.041$), increased application of N to the cash crop after a legume cover crop (6.88, $P=0.047$), and application of N to the cover crop (6.40, $P=0.010$) all had a significant effect on the perceived cash crop yield gain from using 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. Thus, use of conservation tillage likely provides experience to the farmer in dealing with residue management systems that increase the perceived value of using complementary practices, such as cover crops. Furthermore, Abadi Ghadim and Pannell (1999) indicate that this complementary experience may increase skill development and management experience for utilizing cover crops in the farmer's current crop production system. Thus, the value of future information will be reduced, but should be more than made up by increases in gross margin per acre to the farmer.

The application of N after a legume cover crop is likely due to the risk-averse nature of farmers. 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. In a sense, the legume cover crop is a form of insurance for improved cash crop performance, explaining the potentially higher perceived gain from use of a legume cover crop prior to planting of the cash crop. The same logic follows for application of N to the cover crop. Given that maximizing biomass was not a significant factor, it may be the case that applying additional N to the cover crop is to ensure that there are no adverse impacts on cash crop performance.

The only significant demographic factor was high debt (*9.27*, $P=0.006$). It would seem that farmers with high debt may perceive a greater gain from cover crops possibly due to greater investments into conservation practices and structures. The set of farmers that fall in this category may be greater risk takers, and is likely correlated with high farm sales. The lack of the significance for education may be due to the fact that education and experience is not the same thing. While education will make farmers aware of agricultural innovations and start the adoption process, it is experience that will take them down the adoption path and instill in them the value of the agricultural practice being examined.

Perceived high costs (-5.37; $P=0.013$) had a significantly negative impact on the perceived gain in cash crop yield from incorporating cover crops into the cropping system. Pannell (1999) indicates that agricultural innovations not only have to provide benefits in excess of input costs, but must also cover opportunity costs, as well. 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 crop (i.e. in vegetable production systems), cover crops may replace a cash crop, which could have significant opportunity costs. Furthermore, the cover crop itself may be treated as a cash crop (e.g. winter wheat), rather than as a cover crop for soil conservation purposes. This was highlighted in the conceptual framework in equation (7) via the term $NPV_{t=\bar{t}+1}^{n}\left[E\left(\bar{Y}_{v,t}^{c,**} - \bar{C}_{v,t}^{c,*}\right)A_{v,t}^{c,**}\right]$. In addition, if a farmer perceives that there cover crop costs are high, inputs into cover crop production may be reduced to lower production costs, lessening the benefit of the cover crop.

Conclusion

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 make in deciding to adopt and/or retain the use of cover crops on their farm. Pannell (1999) contends that the trialing process of new agricultural innovations is the most important component of the adoption process. This was seen in the conceptual framework as the skills and experience gained from trialing the use of cover crops, which increase the future value of cover crop use in terms of potentially higher gross margins for the cash crop and more widespread adoption on-farm. The econometric model developed from this framework examined the demographic and management factors that affect the perceived gain in cash crop yield when using a cover crop from the trialing process and continued use of the practice.

Model results suggest some potential assistance and outreach strategies that could be used to assist farmers in maximizing the benefits from cover crop use. These include:

- Education and extension efforts emphasizing heavy residue management systems to help avoid potential misconceptions. For example, farmers may assume corn residues are sufficient for meeting soil conservation needs, but Morton and Bergtold (2006) show that maximizing biomass in corn cropping systems with cover crops can potentially increase economic returns and soil conservation benefits.;
- Given the potential gain in complementary skills and experience, conservation programs such as the Environmental Quality Incentives Program and the Conservation Security Program, could be structured to promote the adoption of conservation tillage followed by the sequential adoption of cover crops into the crop production system. At the end of the day, economic incentives are still the primary driving force in determining adoption of agricultural innovations (Pannell, 1999). Using a sequential adoption approach may likely increase the use of both practices by farmers in the Southeast (Bergtold et al., 2007; Leathers and Smale, 1991). In addition, providing subsidies for larger farms may encourage trailing of cover crops and potential future adoption across the entire row crop operation;
- Target conservation assistance and programs to farmers with the highest likelihood of adoption to achieve set societal-environmental goals. For example, based on model results, younger farmers that utilize conservation tillage systems on

moderately sized farms may perceive higher benefits from using cover crops on their operations, making them a target audience for conservation programs.

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