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Effect of Cover Crop Adoption on Nitrogen Use among Conventional and Organic Corn Farms – An Empirical Analysis

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Effect of Cover Crop Adoption on Nitrogen Use among Conventional and Organic Corn Farms – An Empirical Analysis

Abstract

Multiple studies have estimated factors influencing cover crop adoption which include control weed population (Ngouajio et al. 2002), increased soil health (Santhi Wicks and Richard Howitt, 2005), and increased productivity (Johannes M. S. Scholberg, Santiago Dogliotti, Lincoln Zotarelli, Corey M. Cherr, Carolina Leoni and Walter A. H. Rossing, 2010, Jason Bergtold, Jason Fewella, and Patricia Duffy, 2010). An externality of adoption of cover crops that has not been explored is its potential impact on the amount of nitrogen use by farmers. Using a 2009 survey of conventional and organic corn farmers in 7 states of the US, we estimate the factors affecting adoption of cover crops and its impact on nitrogen use. While nitrogen used by farmers is considered as left censored variable, adoption of cover crop is considered as an endogenous dummy variable. The resulting system is a two stage Limited Dependent Variable (LDV) model defined by the amount of nitrogen used by farmers, with endogenous dummy variable that investigates whether the farmer adopts cover crops. We conclude that farmers adopting cover crop technologies, that increase production efficiency, tend to decrease nitrogen fertilizer use. Further, this decrease is significantly higher among organic corn producers compared to conventional corn farmers.

Introduction

With increasing environmental concerns, increasing population, changing tastes and preferences of consumers towards healthier foods, and with more food safety requirements, agronomic practices have changed gradually to provide not only food and fiber but also public goods and other beneficial services from agriculture. Those benefits are referred to multicultural agriculture, which is viewed as a foundation for European model of agriculture (Batie 2003).

In recent years the role of multifunctional agriculture has increased rapidly to meet the needs of increasing population and to provide sustainable practices for the environment. Besides producing private (food and fiber) and industrial goods (bioenergy), agriculture can provide many public goods and services or externalities like land conservation, maintenance of landscape structure, biodiversity preservation , nutrient recycling and loss reduction, and so on (Boody et al. 2005). Multifunctional agriculture is concerned with the fact that agricultural production processes produce not only food and fiber but also various kinds of non-market, non-commodity outputs (Tapani and Jukka 2004).

Though the concept of multifunctional agriculture is very broad the major portion of it is adoption of various agricultural technologies among farmers. Different studies show that different technology adoptions can positively affect soil properties and harvest yields: furrow diking reduces water consumption and improved yield and net returns (Nuti et al. 2009), using some innovations led to a benefit for both production and environmental issues (Blazy et al. 2009). Farmers are able to reduce risk exposure by trying new techniques on their more marginal lands, typically sloped, relatively less productive parcels (at least initially) neighboring to their residences (Arellanes and Lee, 2007). Technology adoption practices can include response of predators to habitat manipulation, good agrarian practices, irrigation scheduling, water saving, conservation tillage, organic farming, erosion reduction, nitrogen fertilization, plastic covered horticulture (Bertuglia et al. 2006) and cover cropping among others. Cover cropping itself can be used for different purposes.

Cover crops can affect soil properties and can improve crop development and yield. Many studies were done to find how cover crops affect different attributes of soil and harvest. Cover crops can influence soil properties, fruit yield and growth and belowground biomass of tomatoes (Sainju at al. 2001). Sainju et al. also show that cover crops effect on soil carbon sequestration and microbial biomass and activities by providing additional residue carbon to soil (2007).

Cover crops can also decrease weed populations in lettuce (Ngouajio at all 2002), legume cover crops can provide nitrogen to the next crop and reduce nitrogen requirements (Larson at all 2001), cover crop management has a significant effect on soil penetration resistance on several occasions, such as grazing of cover crops in grain cropping system can increase economic return and diversify agricultural production system, not damaging the soil (Franzluebbers and Stuedemann 2008), and some cover crops show the best energetic results (Bechini and Castoldi 2009). No tillage in combination with adapted cover crops and crop rotations result in reducing water runoff and consequently soil erosion, and winter cover crops result in significant yield increase of the following cash crops (Derpsch at all 1986). Cover crop mulching offers opportunities for smallholders by addressing soil fertility and weed management constraints (Erenstain 2003).

Another effect of cover crops is decreased nitrogen leaching rates of soil. Though some studies show that sometimes there is no statistically difference in yields between cover crop and non-cover crop treatments (Ritter et al. 1998) majority of the researches agree with the point that cover crops help to reduce the nitrogen leaching. So Sainju et al. show that hairy vetch and crimson clover, being legumes (types of cover crops) fix N from the atmosphere (2002). In different article, Sainju et al. show that cotton and sorghum yields and N uptake can be optimized and potentials for soil erosion and N leaching can be reduced by using conservation tillage, such as no-till or strip till, with vetch/rye biculture cover crop and 60-65 kg nitrogen ha^{-1} (2006).

Other researches show that cover crops reduce soil N_{min} content in autumn and in spring (Kramberger et al. 2000), that cover crops enhanced the soils' capacity for supporting greater microbial biomass nitrogen, potential nitrogen mineralization, and the microbiological function of nitrification and denitrification (Steenwerth and Belina 2004), or that nitrate leaching was reduced by 40% in legume-based systems relative to conventional fertilizer-based system (Tonitto et al. 2005).

Previous literature has suggested that cover crop adoption leads to increased soil Carbon and Nitrogen concentrations. However, there has been no empirical evidence for the same. Given this situation our research focus tries to estimate the following objectives

- To evaluate the factors affecting cover crop adoption among conventional and organic corn producers.
- To analyze the impact on Nitrogen management among farms relative to adoption or non-adoption of this technology.
- To compare adoption rates and changes in chemical nitrogen use among conventional and organic farms

The rest of the paper proceeds as follows. The next section lay out the theoretical framework. This is followed by an econometric model framework that we consider and the assumptions that need to be satisfied. We present readers with an overview of data sources in the next section. Finally the last section concludes with interpretation of results and a discussion on the implication of the study.

Theoretical Framework

Farmers' decision to adopt new technology such as cover crop is influenced by their perception of maximizing expected utility. Thus farmers will adopt new technology such as cover crop when the expected utility from adoption is atleast equal to expected utility from non-adoption. Thus

$$E[U_A(\pi)] \geq E[U_N(\pi)] \qquad 1.1$$

Where $[U_A(\pi)]$ is the utility that a farmer gains from adoption and is a function of profit and $[U_N(\pi)]$ is the utility from not adopting cover crops. Let farmers produce a single output *q* and receive an output price *p,* and the production function faced by the farmers *f*(.) is continuous and twice differentiable. Further, assuming *X* is a vector of inputs and *r* the corresponding vector of unit input prices. Farmers are assumed to be price takers in both the input and output markets. Nitrogen is assumed to be an important input denoted by X_N in corn production. Efficiency in nitrogen use is assumed to vary across farms and is captured by incorporating it in the production function parameter *N*(α) where α represents farmers' characteristics. The production function can thus be written as

$$q = f(N(\alpha), X_N, X_i, \varepsilon) \qquad \forall\, N \neq i \qquad 1.2$$

Where X_i is a vector of all other inputs except nitrogen, and ε is is the variability caused due to factors like climatic conditions and yield variability. Thus the farmer wants to maximize his expected utility and can be defined as a Von Neuman-Morgenstern utility function given by

$$Max\ E\big(U(\pi)\big) = Max \int [U(p\, f(N(\alpha), \varepsilon, X_N, X_i) - r'X)] d\big(G(\alpha)\big) \qquad 1.3$$

Given that *p* and r_N are not random the first order condition for nitrogen input is given by

$$E[r_N \times U'] = E\left(p \frac{\partial f(N(\alpha), \varepsilon, X_N, X_i)}{\partial X_N} \times U'\right) \qquad 1.4$$

This implies that the ratio of the input price over output price can be denoted as

$$\frac{r_N}{p} = E\left(\frac{\partial f(N(\alpha), \varepsilon, X_N, X_i)}{\partial X_N}\right) + \frac{cov\left(U', {}^{\partial f(N(\alpha), \varepsilon, X_N, X_i)}\Big/_{\partial X_N}\right)}{E(U')} \qquad 1.5$$

Where *U'* is the change in expected utility due to change in profits given as

$$U' = {}^{\partial E\left(U(\pi)\right)}\Big/_{\partial \pi} \qquad 1.6$$

Optimal nitrogen use X_N we would need to specify the farmer's preferences given by their utility function (*U(.)*), and the factors affecting the production process (*f(.)*).

We now incorporate in our model the decision by farmers to adopt a new technology like cover crop. This decision is modeled as a binary choice where the farmer can either choose to adopt (*i* = 1) or not (*i* = 0). Adoption of cover crop increases the efficiency of nitrogen use such that

$$N_1(\alpha) > N_0(\alpha) \qquad \forall\, 0 < \alpha < 1 \qquad 1.7$$

Implying that farmers adopting cover crops will need less nitrogen to produce the same amount of output *q*. However, adoption cover crops will add a fixed cost ($F_1 > 0$ and $F_0 = 0$) which could change the marginal cost such that $r_N^1 > r_N^0$. If X^1 is a new optimal choice of input is cover crops is adopted and X^0 is choice of inputs when they are not the first order condition for nitrogen use should satisfy

$$\frac{r_N^1}{p} = E\left(\frac{\partial f(N^1(\alpha), \varepsilon, X_N^1, X_i^1)}{\partial X_N}\right) + \frac{cov\left(U', {}^{\partial f(N^1(\alpha), \varepsilon, X_N^1, X_i^1)}\Big/_{\partial X_N}\right)}{E(U')} \qquad 1.8$$

For farmers not adopting the modified first order conditions then can be denoted as

$$\frac{r_N^0}{p} = E\left(\frac{\partial f(N^0(\alpha), \varepsilon, X_N^0, X_i^0)}{\partial X_N}\right) + \frac{cov\left(U', {}^{\partial f(N^0(\alpha), \varepsilon, X_N^0, X_i^0)}\Big/_{\partial X_N}\right)}{E(U')} \qquad 1.9$$

Thus as defined in equation 1 farmer will adopt cover crop if the expected utility from adoption is higher than that of not adoption. Expected utility under adoption can thus be derived as

$$E\big(U(\pi^1)\big) = \int \Big[U\Big(p\, f(N^1(\alpha), \varepsilon, X_N^1, X_i^1)\Big) - r_N^1 X_N^1 - r_i^1 X_i^1 - F_1\Big]\, d\big(G(\alpha)\big) \qquad 1.10$$

Farmers who do not adopt cover drop have an expected utility function with no fixed cost and can be denoted as

$$E\big(U(\pi^0)\big) = \int \Big[U\Big(p\, f(N^0(\alpha), \varepsilon, X_N^0, X_i^0)\Big) - r_N^0 X_N^0 - r_i^0 X_i^0\Big]\, d\big(G(\alpha)\big) \qquad 1.11$$

Thus, farmers' choice of adoption will depend on input and output prices, cost of new technology, parameters of production technology and farmers' preferences. The empirical application of the above theoretical model follows a two-step procedure that we describe in the next section.

Empirical Model

Nitrogen fertilizer used by farmers who adopt cover crops and those who do not adopt cover crops is estimated. While nitrogen used by farmers is considered as left censored variable, adoption of cover crop is considered as an endogenous dummy variable. The resulting system is a Limited Dependent Variable (LDV) model defined by the amount of nitrogen used by farmers, with endogenous dummy variable that investigates whether the farmer adopts cover crops. Because the censoring precludes unique or sensible solutions for the reduced forms, a condition must be imposed in a system of censored dependent variables (Heckman, 2001). The structural form of the model is given by

$$Y_1^* = X'\beta + Y_2{}'\gamma + u_i$$

We assume that $Y_1 \;\; = Y_1^*$ is continuously observed such that

$$Y_1^* = X'\beta_1 + Y_2{}'\gamma + u_i \quad if\ Y_1 > 0$$

$$Y_1^* = 0 \qquad\qquad\qquad if\ Y_1 \leq 0$$

Further endogeniety is introduced in the model if γ and u_i are correlated. Considering Y_2 is a dummy variable we estimate it using a Probit model to understand the probability of adoption such that

$$Y_2 \begin{cases} 1 = Z'\beta_2 + v_i = Y_2^* \\ 0 \end{cases}$$

Where, Y_2 is a latent variable that is continuously observed. the errors follow the distribution

$$(v_i, u_i) \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho\sigma_u \\ \rho\sigma_v & 1 \end{pmatrix}\right]$$

Thus Y_1 represents the amount of nitrogen used by farmers per acre and is censored at zero. The amount of nitrogen used is dependent on exogenous variables X and a dummy variable Y_2 representing the probability of adopting cover crops, which is potentially endogenous. Probability of adoption of cover crops is dependent on Z variables which are uncorrelated with u_i. . β_i represents $k_i$vectors of unknown parameters that have to be estimated. When the correlation factor ρ is not considered as zero which is the case in our sample then the Log-Likelihood function can be denoted as (Moffatt, 2005)

$$\mathcal{L} = \sum_0 ln\left[1 - \Phi(X_1'\beta_1)\phi\left(\frac{X_2'\beta_2}{\sigma}\right)\right] + \sum_+ ln\left[1 - \Phi(X_1'\beta_1)\frac{1}{\sigma}\phi\left(\frac{Y_1 - X_2'\beta_2}{\sigma}\right)\right]$$

The first term indicates the contribution of all observations with an observed zero. Thus, suggesting that zero observations come not only from adoption of cover crops, but also from the amount of nitrogen used. The second terms accounts for contribution of all observations with non-zero values. The probability in the second term comes from the product of the conditional probability distribution and the density function coming from the censoring rule and observing non-zero values respectively (Fabiosa, 2006).

Endogeneity tests of probability of adoption of cover crops and nitrogen use per acre on the farm are considered. We use the Smith Blundell test to determine exogeneity as proposed by Baum (1999) who computes a test for exogeneity based on the Smith and Blundell's test where, under the null hypothesis, the models are appropriately specified with all explanatory variables as exogenous. Under the alternative hypothesis, the suspected endogenous variables are expressed as linear projections of a set of instruments, and the residuals from the first stage regressions are added to the model.

MacDonald and Moffitt (1980) proposed the use of the decomposition of the marginals in Tobit models to determine the changes in the probability of being above the limit and changes in the value of the dependent variable if it is already above the limit. We use this decomposition to understand the effects of changes in the second stage dependent variable (amount of nitrogen used per acre) due to the independent variables. To understand the effects of the independent coefficient on the dependent variable (in our case the amount of nitrogen use), the change in expectation of this y^* (the unobserved latent variable) can be expressed as

$$\partial E(y^*)/\partial x_j = P(y^* > 0)\,\partial E(y^*|y^* > 0)/\partial x_j + \partial E(y^*|y^* > 0)\,\partial P(y^* > 0)/\partial x_j$$

implying that the total change in the unconditional expected value of amount of nitrogen used is decomposed into two intuitive parts.

a) The change in the expected value of nitrogen used per acre (y*) for those farmers who use some amount of nitrogen, weighted by the probability of being above zero

b) The change in the probability of being above zero, weighted by the conditional expected value of y* (McDonald & Moffitt, 1980).

Considerable literature has evolved in the use of limited dependent variable model with endogenous dummy variable. Amemiya (1974) considers a model in which all endogenous variables are truncated to zero, revealing certain necessary restrictions on the model and suggesting a method of estimation using the indirect least squares method. Nelson and Olson (1978) proposed a two-stage least squares procedure for Tobit analysis proving that the estimates are asymptotically normal. More recent studies have applied these models for specifying effects on adoption of technologies including Blundell and Smith (1989) who compared estimates of marginal and marginal and new conditional maximum likelihood procedures. Goodwin and Mishra (2004) used the simultaneous equation framework to determine multiple job holdings and resulting effects on farming efficiency. A more detailed discussion on use of LDV with dummy endogenous model is presented by Angrist, J.D., (2001).

The marginal effects for the two stage probit-tobit model are tricky to calculate for nonlinear functions of variables (Greene, 2010). Partial effects for a model where a variable enters as a squared term of the variable are calculated as if the variable and its squared term are independent of each other. This may lead to erroneous results (Ai and Norton, 2003). The computation of marginal effects for such variables can be estimated as (Greene, 2010)

$$\delta \quad V = \frac{\partial Prob(y = j|x)}{\partial \, V} + (2V)\frac{\partial Prob(y = j|x)}{\partial \, V^2}$$

Where V is a variable that enters the model both as a linear and a squared term (Ex: Age and Age squared) and x is a set of k_i vector of exogenous variables.

Data

A mail survey developed as part of a collaborative project among six institutes (LSU AgCenter, Cornell University, UC Davis, Michigan State University, World Resources Institute and University of Illinois) was administered to conventional and organic corn farms in seven US states (Illinois, Indiana, Iowa, Ohio, Michigan, Minnesota, and Wisconsin) in Spring 2009. The sample frame for conventional corn farmers was obtained from USDA, FSA under the freedom of information act. A mailing list for organic producers was developed by co-PI's in the project by contacting various certification organizations and agencies that promoted organic farming. A sample of 932 was chosen for organic farmers and 2068 for conventional corn producers to obtain representative results. The sample was stratified with the proportion calculated based on the number of farmers who received LDP payments in each of the seven states. The Total Design Survey Methodology was used (Dilman). The main questionnaire had six main topics, general and farm information, corn field management in the highest and lowest yielding corn field, sources of information and decision making and socioeconomic characterstics of farmers. The initial mailing of the questionnaire occurred in March 2003. A total of 233 completed surveys for the organic corn farmers and 212 completed surveys among conventional farmers were received. There were 428 farmers who did not farm or could not be contacted the effective response rate was 26 percent for organic producers and 13 percent for conventional farmers.

The questionnaire included considerable detail on nitrogen fertilizer practices for corn including type and amount of fertilizer used, type and amount of manure used for corn production, whether farmers adopted cover crops and how long were they allowed to stand in the field before they were incorporated. Other farm management operations that asked farmers if they used practices like yield goal monitors, soil testing, PSNT, rotation with winter grains, adding buffers strips, split application of nitrogen fertilizer and whether tile drainage were adopted, were also included in the questionnaire. Farmers were asked whether they adopted cover crops for nitrogen management. About 54 percent of organic farmers and 35 percent of conventional corn producers who answered this question indicated that they used cover crops in their fields. Total nitrogen used on corn was estimated from survey responses regarding fertilizer use, manure applications and previous cropping history. Two sources were utilized in calculating these conversions which included Agricultural Waste Management Field Handbook (USDA – SCS) and Ohio Livestock Manure Management Guide. Percent Nitrogen in each type of livestock manure was based on mean weight of the livestock and density equations were calculated based on 15% moisture in the manure. Table 1 provides the mean of the variables used in our model for conventional and organic farmers that explained the farmers' attitudes for adoption of cover crops and nitrogen management decisions.

Since soil type and weather vary among farms across states regional differences of adoption intensity across the different states were divided based on ERS region classification. Thus, the seven states were divided into two ERS regions namely northern crescent (N_CRESCENT) and Heartland. 48 percent of organic farms and 67 percent of conventional farms that completed the survey were from the northern crescent region.

Results and Discussions

Relationships between nitrogen used and independent variables including whether or not farmers adopted cover crops were investigated across two models. Dependent variable for our structural model (nitrogen per acre) was defined as a left censored tobit model was estimated using predicted probabilities from our adjoint model that estimated parameters that affected probability of adoption of cover crops using a probit model.

The explanatory variables for the two equations were divided into 3 categories: (i) demographic: region, farmer's age, household income, education, experience, percent share of the off-farm work, type of farm's operation's organization; (ii) socio-economic: farm size, existence of cattle in the farm, importance of farmers relying on cover crops, cooperative extension, and organic fertilizer dealers; (iii) agronomic: if any CRP payment was received, current commercial and legume N management practice change variables relative to 5 years ago.

Dummy variable for rotation with winter grains was included in nitrogen per acre used. Fertilizer use is hypothesized to be positively correlated with rotation with winter grains compared to legumes or cover crops. Farmers who have renovated tile drainage are hypothesized to apply less nitrogen since nitrogen losses through runoffs are significantly decreased. Also, membership in farm management association and farmers relying on information from extension agents may be negatively related to nitrogen application rates. However, farmers who rely more on advice from organic fertilizer or commercial fertilizer dealers may use more nitrogen fertilizer. ISDS_EXT, ISDS_ODE and OP_EDUC are lickert-type variables. Responses to these variables are assumed to be interval scale data that can be analyzed as continuous variables.

Factors affecting adoption of cover crops included a dummy variable that controlled for whether or not farmers received CRP payments. We hypothesize that farmers receiving these payments were more likely to adopt cover crops. We also hypothesize that farmers having a larger share of rented land may be less likely to adopt cover crop. Sloping fields are more likely to be placed under cover crop production since it will help prevent soil erosion and water runoff.

Probit results for the probability of adoption of cover crops are presented in table 2. The proabability of adoption equation has an overall significance at 0.01 level. The coefficients of the parameters estimated have expected signs. Age has a positive impact on probability of adoption. Farmers with many years in agriculture tend not to adopt cover crops. This follows economic theory of adoption which suggests that farmers close to retiring age may not see any utility gained since the profitability of adoption may accrue after they have retired. As the number of acres that farmers farm increase the probability of adoption increases this is true since the cost per acre of adoption decreases with increase in acres thus making adoption of cover crops more attractive. Increase household income has a negative impact on cover crop adoption. This may be due to the fact that farmers with higher income may not want to add additional practices that incur more time on the field and their opportunity cost of leisure is increased. Farms in heartland are more likely to adopt cover crops compared to those of northern crescent and may be due to higher cattle and dairy operations in northern crescent compared to states in heartland region. Farmers who rely more on other farmers for advice who have already adopted cover crops are more likely to adopt this technology. On the other hand farmers relying more on organic fertilizer dealers for information have a lower probability of adoption. Farmers who receive CRP payments are more likely to adopt cover crops as a nutrient and soil management tool.

While the coefficients are helpful in understanding if the parameters have a positive or negative relationship to adoption marginal effects provide information on intensity with which each of the parameters affect the probability of adoption. This is presented in the last column of table 2. An additional year of age increases the probability of adoption by 1.5 percent. An additional year of experience will decrease the probability of adoption by 5 percent. Though the coefficient of farm size is very small. We can conclude that if the farm size increases by 100 acre the probability of adopting cover crop increases by 1.46 percent. Household income is a scaled variable (1:10000) and the marginal effect can be interpreted as an increase in income by 10,000 dollars increases decreases the probability of adoption by 5 percent. As farmers' reliance on other cover crop adaptors and organic fertilizer dealers increase the probability of adoption increases (decreases) by 10 percent (8 percent). Finally farmers receiving CRP payments have a 20 percent higher chance of adoption of cover crops.

Cover crop adoption is assumed to be endogenous to the amount of nitrogen used per acre by farmers. Thus predicted value from our first stage probit model that predict the probability of adoption based on an underlying regression is introduced into our structural equation that investigates the impact of independent variables on intensity of nitrogen used per acre by farmers.

Table 3 shows the results from our tobit model. The last column in the table illustrates the marginal effects as semi-elasticity for ease of understanding for readers. The semi-elasticity explains the change in unit intensity of each coefficient effect on nitrogen use by farmers on percent nitrogen use. Variables with coefficients significantly different from zero include probability of adoption of cover crop, rotation with winter grains, if farms have livestock operations and number of days worked off-farm by farm operators.

The marginal effect suggests that for a one acre increase in cover crop adoption there is a 4 percent decrease in the amount of nitrogen from fertilizer and manure used by farmers. The result suggest that farmers adopting cover crops use it as a substitute for other types of nitrogen for the next crop. The result substantiates hypothesis by many authors who have thought that cover crops apart from reducing soil erosion also help increase soil health (Lu, Watkins, Teasdaleand Abdul-Baki, 2000). Farmers who rotate corn with winter grain increase their nitrogen use by 3 percent compared to those who do not.   This result follows economic theory that cash grains deplete soil nutrients faster and need higher chemical and manure nitrogen fertilizers to maintain or increase yields. Farmers who have livestock operations tend to use 3 percent more nitrogen per acre compared to those who do not. The result suggest that manure operations may often be a manure disposal issue rather than a calculated application for nutrient management as other authors have found (Musser, Shortle, Kreahling, Roach, Huang, Beegle and Fox, 1995). Finally farmers who work more number of hours off the farm tend to use less nitrogen compared to those work more on-farm. Thus an additional three month off-farm work in a year decreases the amount of nitrogen use per acre by 5 percent. The results suggest opportunity cost of time in application of additional nitrogen compared to working off the farm and marginal cost difference between farmers who work more on-farm compared to those who work off-farm.

Conclusions

Studies have shown that cover crops have been adopted for various reasons including weed control, increased soil health, increased productivity. An externality of adoption of cover crops that has not been explored is its potential impact on the amount of nitrogen use by farmers. The paper investigates whether there is significant impact on nitrogen use due to adoption of cover crops in organic and conventional farms. Adoption of cover crops has been limited for many reasons. Authors have noted that farmers growing continuous cash crops may see this technology as an added expense with little cost advantages (Sanju and Whitehead, 2006). We model these considerations in our constraints and suggest that farmers will adopt this technology when the marginal utility, governed by profits, from adopting is at least equal to not adopting. Our survey shows that there are significant savings in input costs mainly nitrogen due to adoption of cover crops. The paper provides evidence on a causality relationship between adoption of cover crops and nitrogen management among farmers in the survey area. Policies and outreach efforts geared to promoting adoption of cover crops and its implication on nitrogen use could make probability of adoption among farmers higher.

Table 1: Descriptive Statistics

Variable	Description	Mean for Organic Farms	Mean for Conventional Farms
COVER_CROP	Equal to '1' if cover crop incorporated in the corn yield, '0' otherwise.	0.538835	0.34681
NCRECENT	Equal to '1' if the farm is in Northern Crescent Region, '0' otherwise	0.472103	0.67159
OP_AGE	Farmer's age.	52.93396	54.36571
OP_EDUC	Farmer's highest level of education.	2.770642	2.175896
FARM_EXP	Number of years of farming.	29.92453	30.58796
HH_INCOME	Total household income.	3.257732	2.87532
ISDS_COV	Equal to '1' if importance of farmers relying on cover crops on decision making is low, '2' if moderate,'3'if high, and '4' if very high.	4.036649	2.136813
ISDS_EXT	Equal to '1' if importance of extension on decision making is low, '2' if moderate, '3'if high, and '4' if very high.	2.107345	2.875961
ISDS_ODE	Equal to '1' if importance of organic fertilizer dealers on decision making is low, '2' if moderate, '3'if high, and '4' if very high.	2.86631	1.28694
SH_OFFARM	Percent share of the off-farm work for a year.	0.262035	0.365782
TOTACRES	Number of total acres of the farm.	933.9644	787.26578
FRM_ORG	Equal to '1' if farming operation is organized as family or individual, '2' if legal partnership, and '3' if incorporated under state low.	1.279279	1.126893
RISKAVERSION	Equal to '1' for the lowest 25% quartile of the distribution of risk aversion, '2', '3', and '4' for subsequent quartiles.	2.545064	2.15648
LIVESTOCK	Equal to '1' if the farm has the livestock, '0' otherwise.	0.67382	0.598264
ROTATION_W	Equal to '1' if the farmer follows a winter grain crop rotation with corn	0.3106061	0.276582
CRP_PMT	Equal to '1' if the farmer got CRP payment, '0' otherwise.	0.227468	0.46894
NITROGEN	Amount of nitrogen used per acre.	53.924398	84.75984
TILE_DRAIN	Equal to '1' if the farm has artificial drainage, '0' otherwise.	0.298406	0.218978
MANURE	Equal to '1' if manure was used, '0' otherwise.	0.577376	0.375986
PAST_CN	Equal to '1' if less commercial N per acre, '2' if the same amount, '3' if more commercial N per acre was used by farmer than 5 years ago, and '4' if it doesn't apply to farmer's case.	3.00178	4.898723
PAST_LN	Equal to '1' if less legume N per acre, '2' if the same amount, '3' if more legume N per acre was used by farmer than 5 years ago, and '4' if it doesn't apply to farmer's case.	2.394006	1.497825
TOTFARM	Farm income	321394.4	281937.1
SH_CROP	Percentage share of the crop land	0.3270387	0.3270387
PCOVER	Predicted values of cover crop adoption form probit model		

Table 2: Estimation Results for Probit Model of the Cover Crop Adoption

Variable	Coefficient	Standard Error	Marginal Effect
OP_AGE	0.038486**	0.01888	0.015301
OP_EDUC	-0.07002	0.136631	-0.02784
FARM_EXP	-0.1314***	0.053542	0.05224
EXPSQ	0.00226***	0.001036	0.000899
TOTACRES	0.000367***	0.000148	0.000146
HH_INCOME	-0.12938***	0.053405	-0.05144
RENT_CROP	-0.11276	0.114789	-0.04483
NCRECENT	-0.42167*	0.267113	-0.16671
ISDS_COV	0.232812*	0.131134	0.092562
ISDS_ORG	0.114494	0.116085	0.045521
ISDS_ODE	-0.21059*	0.115494	-0.08373
CRP_PMT	0.54105*	0.328359	0.209468
SLOPE_D	-0.41399	0.355918	-0.1637

Table 3: Estimation Results for Tobit Model of the Nitrogen Use per Acre

Variable	Coefficient	Standard Error	Marginal Effect
PCOVER	-116.03**	61.99498	-4.37179
ROTATION_W	79.5923**	44.1586	2.998899
FARM_INC	-1.69563	1.567334	-0.06389
LIVESTOCK	77.97511***	36.6004	2.937967
TOTACRES	-0.00383	0.006593	-0.00014
ISDS_EXT	13.34633	11.37286	0.502866
ISDS_ODE	-6.20541	12.51424	-0.23381
TILE_DRAIN	-28.8345	28.39946	-1.08643
OP_EDUC	-19.3671	18.91484	-0.72972
DYS_OFFF	-13.386*	10.07933	-5.0436

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