[DRAFT VERSION]

A Comprehensive Analysis of Adoption of Energy Crops, GM Crops and Conservation Practices

Haluk Gedikoglu
Assistant Professor of Agricultural Economics
Cooperative Research Programs
Lincoln University of Missouri
Jefferson City, MO 65101
E-mail: GedikogluH@lincolnu.edu

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Abstract

The future of the US agriculture relies on sustainable resource use and income generation for farmers, and maintaining the environmental quality. Hence, farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified crops, and conservation practices. The objective of this study is, by using a multivariate probit model, to conduct a comprehensive analysis of the impact of certain socio-economic factors on adoption of Miscanthus, Roundup Ready® soybean, and maintaining a 100 foot setback between water resources and manure application areas. The results of the current study show that different policies will be needed to promote adoption of technologies with different objectives.

Keywords: Sustainable Agriculture, Technology Adoption, Multivariate Probit

The future of the US agriculture relies on sustainable resource use and income generation for farmers, and maintaining the environmental quality. Hence, farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified (GM) crops, and conservation practices. For the sustainable resource use objective, we analyze the production of bioenergy. The Energy Independence and Security Act of 2007 set a renewable fuel standard of 36 billion gallons of ethanol production by 2022, of which 21 billion gallons are to come from cellulosic ethanol. Cellulose fiber is a major component in plant cell walls, which allows ethanol to be produced from plant sources that do not compete with food prices. Miscanthus is one of the major energy crops that have been analyzed as source of cellulosic biomass. The studies show that Miscanthus has high yield potential, which varies between 10 ton / ha and 36 ton / ha (Khanna et al., 2008). Miscanthus requires less fertilizer and herbicide application than other energy crops, which makes Miscanthus to be more profitable (Khanna et al., 2008). The downside of growing Miscanthus is its high establishment cost (Khanna et al., 2008).

For the income generation objective, we analyze the adoption of Roundup Ready® soybean, which is a GM crop. Roundup Ready® soybean allows farmers to apply only one herbicide instead of multiple herbicides. Hence, Roundup Ready® soybean helps farmers to decrease herbicide application costs. For the environmental quality concern, we analyze adoption of a nutrient management practice. Livestock operations are significant sources of water pollution in the U.S (Aillery et al., 2005). Livestock production produces a by-product, manure, which contains nutrients such as nitrogen and phosphorous and without proper management, these nutrients can degrade water sources (Aillery et al., 2005). Farmers' adoption of nutrient management practices, such as "maintaining a 100 foot setback between streams and lakes and manure application areas" can prevent the water pollution and enhance the environmental quality.

Previous studies focused on adoption of an individual practice among inter-related technologies. Khanna (2001) explains that when adoption decisions of inter-related technologies are modeled as independent single equations, the estimates for these single equations will be inefficient. Hence, a bivariate or a multivariate model should be used. The objective of this study is, by using a multivariate probit model, to conduct a comprehensive analysis of the impact of certain socio-economic factors on adoption of Miscanthus, Roundup Ready® soybean, and maintaining a 100 foot setback between streams and lakes and manure application areas. We specifically focus on the impact of farm size, off-farm income, and sources of information. To our knowledge this is the first study that provides a comprehensive approach to adoption of technologies and practices with different objectives.

Theoretical Framework

To represent the household's voluntary decision regarding technology adoption, a household utility maximization model is constructed. The current model is extension of the agricultural household models by Huffman (1980) and Cornejo, *et al*. (2005). The household problem can be represented as;

(1) $$\max_{C, L_e, L_a, K_a} U\left(C, L_e, E(L_a, K_a)\right)$$

$s.t.$

(2) $$P_c.C + r.K + r.K_a + W.L_{on} \leq P_q.Q + W.L_{of}$$

(3) $$L_{on} + L_{of} + L_a + L_e \leq 24$$

(4) $$Q \leq F(K, L_{on})$$

where, U (.) is the utility function of the household, C is the consumption, L_e is leisure, E(.) is the level of environmental quality, which is an increasing function of amount of labor, L_a , and amount of capital, K_a , reserved for adoption of conservation practices.

The budget constraint is represented in equation (2). P_c is the price for the consumption good, P_q is the price for the farm output, Q is the farm output and W is the wage rate for the off-farm work. r is the market interest rate and K is the capital for production activities. The time constraint is represented in equation (3). The total amount of time available for the household is 24 hours. L_{on} is the amount of time provided for on-farm activities, L_{of} is the time devoted to off-farm work. For the current model both on-farm labor and off-farm labor are exogenous to model, to reflect that the situation that labor devoted to adoption of new conservation technologies is determined after on-farm and off-farm labor decisions are made.

The technology constraint is reflected in equation (4). Where, F(.) is the neo-classical production, which is an increasing function of amount of capital K, and amount of on-farm labor, L_{on} . To maximize consumption, farmers will always produce at the level available by the technology; hence the technology constraint is always binding $Q = F(.)$.

To find the solution to the household problem, the structured Langrangian becomes;

$$L: \max_{C, L_e, L_a, K_a} U\left(C, L_e, E(L_a, K_a)\right) + \lambda\left(P_q.F(K, L_{on}) + W.L_{of} - P_c.C - r.K - r.K_a - W.L_{on}\right) + \mu\left(24 - L_{on} - L_{of} - L_a - L_e\right)$$

the first order conditions become;

(5) $\frac{\partial L}{\partial C}: U_1' - P\lambda \leq 0 \qquad C^* \geq 0$

(6) $\frac{\partial L}{\partial L_e}: U_2' - \mu \leq 0 \qquad L_e^* \geq 0$

(7) $\frac{\partial L}{\partial L_a}: U_3' \frac{\partial E(.)}{\partial L_a} - \mu \leq 0 \qquad L_a^* \geq 0$

(8) $\frac{\partial L}{\partial K_a}: U_3' \frac{\partial E(.)}{\partial K_a} - r\lambda \leq 0 \qquad K_a^* \geq 0$

(9) $\lambda\left(P_q.F(K, L_{on}) + W.L_{of} - P_c.C - r.K - r.K_a - W.L_{on}\right) = 0$

(10) $\mu\left(24 - L_{on} - L_{of} - L_a - L_e\right) = 0$

where equations (5)-(8) are the first order conditions for consumption, leisure, labor and capital for adoption of new technology. Equations (9) and (10) reflect that either the constraints hold with equality, hence the inside of the parentheses equal zero and the Langrangian multipliers λ and μ are non-zero, or the Langrangian multipliers are zero and inside of the parentheses are positive. C^*, L_e^*, L_a^*, K_a^* are the optimal decision variables. U_1', U_2', U_3' represent first order partial derivatives of the utility function with respect to consumption, leisure and environmental quality.

Either the assumption that farmers will always have a positive amount of consumption and leisure, or a strict concavity assumption of the utility function (i.e. logarithmic utility function), will lead equation (5) and (6) to hold with equality. Hence, the values of the Langrangian multipliers λ and μ are; $\lambda = \frac{U_1'}{P_c}$, $\mu = U_2'$.

Empirical Model

For the empirical model, the adoption decision that farmers make for the practices can be represented as an extension of the theoretical model discussed in the analytical framework. After farmers make their optimal choices of the choice variables; C^*, L_e^*, L_a^*, K_a^*, the utility gained by optimal choice variables is compared to the utility gained by choosing the critical values L_a^C and K_a^C. If the utility gained by the optimal choices is bigger or equal than the utility from the critical value, then the farmer adopts the practice. It is also assumed that the maximized utility have a random factor, ε, which is assumed to have a normal distribution. The maximized utility function is also assumed to be impacted by fixed factors such as age, education, perceptions and so on. These factors are showed by Z, which is a vector, in the maximized utility function.

If $\mathrm{U}\left(C^*, L_e^*, E(L_a{}^*, K_a{}^*), Z, \varepsilon\right) \geq \mathrm{U}\left(C^*, L_e^*, E(L_c, K_c), Z, \varepsilon\right)$ then the technology is adopted

and

if $\mathrm{U}\left(C^*, L_e^*, E(L_a{}^*, K_a{}^*), Z, \varepsilon\right) < \mathrm{U}\left(C^*, L_e^*, E(L_c, K_c), Z, \varepsilon\right)$ then the technology is not adopted. Hence,

$$y_i = 1 \quad \text{if } \mathrm{U}(\mathrm{L}_\mathrm{a}^*, K_\mathrm{a}^*;) \geq U(L_c, K_c;)$$

$$y_i = 0 \quad \text{if } \mathrm{U}(\mathrm{L}_\mathrm{a}^*, K_\mathrm{a}^*;) < U(L_c, K_c;)$$

Most of the empirical studies focus on either adoption of an individual practice within a multi-component technology package or adoption of the package as a whole (Khanna 2001; Dorfman 1996). The studies that analyze individual practices within a package, treat adoption of each practice as independent. The single equation estimation of adoption of individual practices within a package ignores the correlation among the adoption of inter-related practices (Khanna

2001; Wozniak 1984). The correlation might arise from either the unobserved factors, which might impact the adoption of all the practices in the package, or the adoption of one practice may be conditional on adoption of another practice (Khanna 2001; Dorfman 1996). Khanna (2001) explains that when adoption decisions of inter-related technologies are modeled as independent single equations, the estimates for these single equations will be inefficient; hence the variance of the estimated coefficients will be large. In the current study, the producers who have a CNMP are expected to adopt practices such as soil testing, grass filters and record keeping jointly. Hence, adoption decisions for the practices are expected to be correlated so a multivariate probit model will be used. The multivariate probit model can be represented as;

$y_{1i} = \mathbf{X}_{1i}\boldsymbol{\beta}_{1i} + \varepsilon_{1i}$, $\quad \mathrm{y}_{1i} = 1$ if Miscanthus is adopted, $\quad$ 0 otherwise,
$y_{2i} = \mathbf{X}_{2i}\boldsymbol{\beta}_{2i} + \varepsilon_{2i}$, $\quad \mathrm{y}_{2i} = 1$ if Rounup Ready Soybean is adopted, $\quad$ 0 otherwise,
$y_{3i} = \mathbf{X}_{3i}\boldsymbol{\beta}_{3i} + \varepsilon_{3i}$, $\quad \mathrm{y}_{3i} = 1$ if Maintaining Setback is adopted, $\quad$ 0 otherwise.

where $\boldsymbol{X}_{ki}$ is the vector that includes the values for the variables that form the deterministic part of the utility function for the observation *i*, where *k* ={1,2,3} and $\boldsymbol{\beta}_{ki}$ is the vector that includes the coefficients to be estimated. The distribution of the error terms ε_k is given as:

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \sim N\left[\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 \end{bmatrix}\right]$$

The error terms ε_k have a multivariate normal distribution with mean zero and variances σ_k^2 equal to one and off-diagonal elements showing the covariances σ_{kj} between two error terms ε_k and ε_j, for which $k \neq j$ (Greene, 2008).

If the covariances become zero, this model becomes four univariate probit models. The probabilities of adopting practices are calculated by evaluating multiple integrals, using the numerical methods (Cameron and Trivedi 2005). For example, the probability of adopting all three of the technologies is;

$$\Pr[y_1 = 1, y_2 = 1, y_3 = 1] = \int_{-\infty}^{X_1\beta_1} \int_{-\infty}^{X_2\beta_2} \int_{-\infty}^{X_3\beta_3} \varphi(\varepsilon_1, \varepsilon_2, \varepsilon_3) d\varepsilon_1 d\varepsilon_2 d\varepsilon_3$$

where $\varphi(\varepsilon_1, \varepsilon_2, \varepsilon_3)$ is the standardized multivariate normal density function.

Data

A mail survey of 3000 farmers that have livestock and land for crop production or pasture in Missouri and Iowa was conducted in spring 2011. Before random sampling, farmers were stratified by farm sales. Farmers with farm sales less than $10,000 were not sampled. This eliminates most of the hobby farmers (Hoppe and Banker, 2006). The survey was designed and conducted following the methodology of Dillman (2000). A pretest was conducted and the survey was modified in response to feedback received. A cover letter and survey were sent, followed by a postcard reminder and a second cover letter and survey. The response rate for the survey was 21 percent.

Summary statistics and the hypothesized impact of each variable are presented in table 1. For the education, the highest category was high school education. Thirty-four percent of the farm operators had year round off-farm employment. Relatively smaller portion of farm operators had seasonal off-farm employment. Forty-three percent of the survey respondents were from Missouri and the rest were from Iowa. Forty percent of the respondents had farm sales (including both crop and livestock sales) between $100,000 and $249,999, which was the largest category. Fifty-eight percent of the farmers had leased land. For the influence on the agricultural production decisions, other farmer had the highest influence.

Results

For the regression results, the hypothesis that all the regression coefficients except the constant term are zero is rejected with a p-value of 0.000, so the multivariate probit regression is significant at 1% significance level. Education of the farm operator is not found to be significant for *Miscanthus*, however farmers with less than high school education and farmers with graduate degree are less likely to adopt Roundup ready soybean than farmers with high school education. Hence, there is no linear relationship between education and adoption of roundup ready soybean. On the other hand farmers with bachelor degree are more likely to adopt maintaining setbacks than farmers with high school degree. Overall, education shows different impact for different technologies. Off-farm income, both unearned and earned, was not significant for all the technologies. Farmers in Missouri are less likely to adopt Roundup ready soybean than farmers in Iowa. However, locational differences are not influential for Miscanthus and maintaining setbacks. Farm sales have negative impact on adoption of Miscanthus and maintaining setbacks, while it has positive impact on Roundup ready soybeans. Hence, larger farm are more likely to adopt a GM crop, but less likely to adopt energy crops and conservation practices. This could be due to profit orientation of the farm. Information sources have different impact on three technologies. For Miscanthus, other farmers have negative, but university extension has positive impact. For roundup ready soybeans, banking institutions have positive impact. For maintaining setbacks, none of the information sources have statistically significant impact.

Conclusion

The future of the US agriculture relies on sustainable resource use and income generation for farmers, and maintaining the environmental quality. Hence, farmers are expected to adopt various technologies and practices, such as energy crops, genetically modified crops, and conservation practices. The objective of this study was, by using a multivariate probit model, to conduct a comprehensive analysis of the impact of certain socio-economic factors on adoption of Miscanthus, Roundup Ready® soybean, and maintaining a 100 foot setback between water resources and manure application areas. The results of the current study showed that different policies might be needed to promote adoption of technologies with different objectives. Larger farms focus more on the profits and have delays in adoption of energy crops and conservation practices. The university extension programs have influence on energy crops, but not the conservation practices. The cost might be the problem. The negative influence of other farmers should be focused on by outreach programs to promote adoption of energy crops.

Table 1. Variable Names, Description, Means and Hypothesized Effect

Variable	Description	Mean	Hypothesized Effect
Education			
Less than high school	1 if has, 0 otherwise	0.20	-
High school degree	1 if has, 0 otherwise	0.29	Base
Some college or Vocational school	1 if has, 0 otherwise	0.24	+
Bachelor degree	1 if has, 0 otherwise	0.16	+
Graduate degree	1 if has, 0 otherwise	0.05	+
Off-Farm Income			
Unearned	1 if has retirement, dividend or interest income, 0 otherwise	0.35	+
Seasonal	1 if has year round off-farm work, 0 otherwise	0.11	?
Year Round	1 if has year round off-farm work, 0 otherwise	0.34	-
Hire Non-Family Labor	1 if hires non-family labor, 0 otherwise	0.33	-
Missouri	1 if the farm is located in Missouri, 0 if the farm is located in Iowa	0.43	?
Farm Sales			
$10,000 - $99,999	1 if has, 0 otherwise	0.27	Base
$100,000-$249,999	1 if has, 0 otherwise	0.40	+
$250,000 - $499,999	1 if has, 0 otherwise	0.21	+
$500,000 +	1 if has, 0 otherwise	0.12	+
Leased Land	1 if has leases land, 0 otherwise	0.58	-
Erosion Problem	1 if has erosion problem, 0 otherwise	0.66	+
Number of Animals	Total number of animals in animal units	212	-
Hay	1 if grows, 0 otherwise	0.49	-
Pasture	1 if grows, 0 otherwise	0.47	+
I am concerned about global warming	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.70	+
Other farmers have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.55	+
Banks have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	1.96	-
Extension have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.16	+

Table 2. Regression Results

Variable	**Miscanthus**		**RR Soybean**		**Setbacks**	
	Coeff.	p-value	Coeff.	p-value	Coeff .	p-value
Education						
(*Base = High School*)						
Less than High School	-0.34	0.669	-1.19	0.006	-0.57	0.130
Some College or Vocational School	-0.26	0.668	-0.18	0.599	-0.08	0.824
Bachelor	0.48	0.462	-0.20	0.606	0.94	0.056
Graduate	-0.09	0.898	-1.46	0.031	-0.04	0.940
Off-Farm income						
Unearned	0.10	0.836	0.35	0.253	0.28	0.349
Seasonal	-0.18	0.822	0.12	0.799	0.40	0.386
Year Round	-0.58	0.322	0.33	0.332	0.24	0.470
Hire Non-Family Labor	-0.29	0.636	-0.39	0.206	0.12	0.691
Missouri (*Base = Iowa*)	-0.19	0.702	-0.90	0.002	-0.18	0.524
Farm Sales						
(Base = $10,000-$99,000)						
$100,000-$249,999	-0.26	0.014	0.27	0.071	-0.36	0.005
$250,000 - $499,999	-6.71	0.976	0.55	0.006	-0.45	0.347
$500,000 +	-0.90	0.483	0.39	0.532	5.19	0.986
Leased Land	-0.25	0.607	0.23	0.469	0.61	0.040
Erosion Problem	-0.03	0.955	0.37	0.255	-0.10	0.736
Total Animal Units	0.00	0.630	0.00	0.472	0.00	0.982
Hay	-1.08	0.086	1.00	0.005	0.72	0.026
Pasture	1.25	0.060	0.21	0.532	0.29	0.354
Global Warming	0.18	0.312	-0.22	0.049	0.24	0.024
Influence on Agricultural Production						
Other Farmers	-0.49	0.071	0.08	0.537	-0.02	0.847
Bank	0.55	0.100	0.13	0.094	0.22	0.307
Extension	0.64	0.057	-0.08	0.574	-0.08	0.547
N	270					
Pseudo R-squared	0.42					
Wald Chi-square	180					
p-value for Wald chi-square	0.000					

Note: Three asterisks (***) indicate significance at 1% level, two asterisks (**) at the 5% level, and one asterisk (*) at the 10% level.

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