Willingness of Agricultural Landowners to Supply Perennial Energy Crops

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24- 26, 2011.

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The authors would like to thank Frances Homans, Linda Meschke, Kent Olson and Joan Stockinger for their insightful comments and feedback. We would also like to thank members of the APEC Environmental Economics Seminar. Funding for this research was provided by the Xcel Energy Renewable Development Fund.

Abstract

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A survey of Minnesota agricultural landowners was conducted to elicit farmers' willingness to supply perennial bioenergy crops. The survey area in the northern Corn Belt region is primarily planted with corn and soybean. Using dichotomous choice questions, the respondents were asked about their willingness to grow perennial grasses and short rotation woody crops (SRWC) given a range of expected net incomes relative to current net incomes. The survey included questions about farmers' attitudes about the environment and renewable energy, perceived barriers to growing perennial crops, land tenure, and demographic information.

The results from this survey add to the broader understanding of farm households' willingness to participate in the bioenergy market by growing perennial crops. At non-negative relative net incomes, on average forty-eight percent of farmers were wiling to grow SRWC on at least some of their land with no significant difference between percentages at each relative net income. Seventy-two percent of farmers were willing to grow perennial grasses at non-negative relative net incomes. Farmers were more willing to supply grasses than SRWC at a given relative net income. This may be due to the longer commitment period, longer lapse in income, higher unavailability of harvesting equipment and costs of reconversion of SRWC compared to perennial grasses. Some farmers (17%) are willing to grow perennial grasses at net incomes that are lower then their current net incomes. In contrast the percentage of respondents willing to grow SRWC at lower relative net incomes was not statistically different from zero. Perennial acreage and share of total acreage were non-decreasing in relative net incomes.

This study illustrates the importance in understanding farm households' willingness to supply when estimating aggregate supply in emerging bioenergy markets. Net incomes from growing perennial bioenergy crops must be at least as high as their current net income for more then a small share of farmers to be willing to supply in the bioenergy market. Farmers must also have higher returns than those from perennial grasses to be as likely to grow SRWC. Increasing relative net incomes from perennial crops does increase the quantity of perennial crops supplied with most of the increase coming from farmers who already participate in the market by increasing their perennial acreage.

Keywords: Perennial Bioenergy, Minnesota, Farmer survey, Crop Adoption

1. Introduction

Agricultural land is under increasing pressure to produce non-cornstarch bioenergy feedstocks to reduce dependence on fossil fuels. This market is emerging to meet the mandate set forth by the Energy Independence and Security Act of 2007 to produce twenty one billion gallons of non-cornstarch gasoline additives (e.g. sugar, cellulose) by 2022 as well as biopower and bioheat demand mandated by state renewable portfolio standards. Perennials such as grasses and short rotation woody crops (SRWC) can potentially meet feedstock production demands in this emerging market. These new generation crops present challenges as well as opportunities to farm landowners.

Cornstarch based biofuel feedstock production is no different from growing corn for feed. The additional demand for feedstock increases the price received per pound, but has no effect on the agricultural practices necessary to produce corn. In contrast, non-cornstarch biofuel, bioheat, and biopower feedstock production will likely utilize biomass from unconventional perennial crops such as grasses and short rotation woody crops in addition to conventional crop residuals.

New cropping systems require a significant investment of time, effort, and capital to implement. Even if expected returns are high, risks such as a loss of grain subsidies, drain tile damage, biomass price volatility and reconversion costs can keep farmers from participating. However, soils with marginal productive capacity for conventional row crops have the potential to support perennial bioenergy crops that yield higher returns due to the relatively lower input costs. In this way, farm households that grow perennial bioenergy crops on a portion of their farmland can reduce aggregate farm risk by spreading revenue (price and yield) and input cost volatility across commodities.

Perennial bioenergy feedstock can also supply non-market services to farm households. Examples include soil retention, wildlife viewing, and hunting. As farm households face more choices about crops to plant, and as the public value of those choices becomes more apparent, there is a growing need to understand the relationship between farm household attitudes and perceptions, monetary returns, and crop choices. This is especially true in the western Midwest where anti-corporate farming laws limit acreage under non-family corporate arrangements (Welsh 2001). How farmers anticipate making decisions in this emerging market has implications across the agricultural sector affecting the supply and prices of food, fiber, bioenergy, and ecosystem services.

2. Objective

The objective of this study is to estimate farmer willingness to supply perennial bioenergy crops using a stated preference survey.

3. Literature Review

There is a growing interest in the social and economic literature in integrating attitudes and perceptions with profit maximization to both understand how farmers make decisions and predict how they will behave as incentives change. Social sciences such as psychology, political science, and environmental science, among others, have a long history of social behavior research. Economics, using the notion of utility theory, has allowed for the inclusion of social variability across different types of consumers. Utility theory has been used to understand the behavior of firms including individuals and households involved in production such as is the case with non-corporate farm households.

3.1. Perennial Bioenergy Crop Adoption

Utility theory can augment the profit maximization theory of the firm to understand and predict a firm's behavior. In agricultural economics, inclusion of the notion of utility of farm households has been used to explain both revealed preference (behavior) and stated preferences.

3.2. Risk Aversion and Perennial Bioenergy Crops

Larson (2007, 2005) used a hypothetical 2,400-acre grain farm in northwest Tennessee to evaluate the willingness to supply biomass under varying assumptions about risk aversion in a utility framework. In the study, they found that biomass markets can reduce risks for farmers by diversifying production and allowing production on marginal lands.

3.3. Stated Choice

Emerging markets inherently contain very little revealed preference data. This necessitates the use of stated preference research to estimate the willingness of farmers to supply biomass and ecosystem services. Studies began to emerge in the 1990s that focused on farmer's willingness to adopt new environmentally improving practices using either revealed or stated preference data. In a stated preference survey, Jolejole (2009) added to the literature in three important aspects. First, their study expanded on the set of explanatory variables. The novel variables included characteristics of the required practices or cropping systems in addition to farmer and farm characteristics. Second, the paper used a direct payment vehicle for ecosystem services. Third, they move from a discrete choice model (participate or not) to a hurdle model allowing for continuous farm level supply functions contingent on willingness to participate. More recently, a number of stated preference methods were used to identify farmer's attitudes about growing energy crops. Paulrud (2010) used a choice experiment to identify the values that Swedish farmers place on different crop characteristics and their willingness to grow energy crops.

3.4. Social Decision of Farmers

The social decision literature includes both informal and formal models for understanding the decisions that farmers make which are quite different from the normative profit maximization models traditionally used in agricultural economics. Willock (1999) argues that a there is a "large and increasing literature, which suggests that the behavior of farmers is not driven only by the maximization of profit." A central construct to this social science literature is that attitudes influence behavior. Underlying these attitudes are beliefs and values. This relationship can be modeled by the Theory of Reasoned Action (Fishbein and Ajzen, 1975) which states, briefly, that ... . While informative, the Theory of Reason Action is criticized as being inadequate (Willock 1999). Inclusion of a broader spectrum of variables beyond attitudes and values known to influence behavior both directly and indirectly is helpful in understanding how farmers make decisions.

The transactional model of behavior suggests that outcome (behavior) variables can be directly influenced by antecedent and/or mediated by goals and objectives. This allows for a formal analysis such as structural equation modeling (Valerand et al., 1992). SEM uses goodness of fit testing of empirical data that can be used to comparatively analyze a set of hypothetical models. This allows behavior models to begin to move beyond strictly correlation relationships and allows understanding of how antecedent, mediation, and outcome variables affect each other (Willock 1999).

In a study of the roles of attitudes and objectives in farmers' decision making, Willock (1999) uses attitude and objective variables and business and environmentally oriented farming behaviors in a mediating variable model. This model allows for variables to at the same time directly and indirectly affect behavior.

4. Conceptual Model

In contrast to annual row crops, perennial crop production requires a multiyear acreage decision by agricultural landowners in which an initial investment in perennial establishment is recovered in future years. We adopt a simple net present value model where a representative farmer chooses the acreage of perennial and conventional crop production. The farmland is homogenous and has a total arable area of A acres. Time steps are equal to one year and T is the exogenous optimal rotation period for perennial crop production. Crop prices, yields, and costs are known with certainty[1]. The farmer's objective function is:

$$\max_{a_p, a_c \geq 0} \quad \sum_{t=0}^{T} \frac{1}{(1+\delta)^t} \pi_t (a_p, a_c) - C \quad s.t. \quad a_p + a_c \leq A \tag{1}$$

where a_p is the perennial bioenergy crop acreage decision from $t=(0,T)$; a_c is the conventional crop acreage decision from $t=(0,T)$; d is the discount rate ($r>0$); C is the cost of establishment; and π_t *is* the profit function. The profit function is:

$$\pi_t = a_p \left(p_{p,t} y_{p,t} - v_{p,t} \right) - s_p f_{p,t} + a_c \left(p_{c,t} y_{c,t} - v_{c,t} \right) - s_c f_{c,t} \tag{2}$$

where p_t is the commodity price; y_t is the commodity yield; v_t is the variable cost; f_t is the fixed cost and s_t is an indicator function that equals 1 when $a>0$ and 0 otherwise. If the constraint holds with equality ($a_p+a_c=A$), all arable acreage is used for crop production, then the objective function is reduced to a single decision of perennial acreage with the remainder of the land staying in conventional crop production. Perennial crop yield is a concave function of time after establishment. Initially the perennial yield is increasing at a decreasing rate, reaching a maximum, and declining until the end of the optimal rotation period. The interior solution is where the sums of discounted marginal profits for perennial and conventional crop production are equal.

The basic objective function equation **Error! Reference source not found.** assumes linearity of the decision maker's utility and contains underlying assumptions about capital markets, and risk preferences of farmers. In the proceeding sections, we relax these assumptions to understand their role in the decision process.

4.1. Liquidity Constraints

In addition to intertemporal preferences, agricultural landowners likely face liquidity constraints due to imperfect capital markets (Haraker et al., 1997). These liquidity constraints cause farmers to prefer regular to irregular yearly incomes. Perennial crop production income is highly irregular due to the concave shape of the perennial yield function. The representative farmer's objective function is:

$$\max_{a_p \geq 0} \quad \sum_{t=0}^{T} \frac{1}{(1+r)^t} u\left(\pi_t (a_p) - C\right) \quad s.t. \quad a_p \leq A \tag{3}$$

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[1] Price, yield, and cost certainty is relaxed in section 4.2.

[2] The utility function can be either concave or convex as we have made no assumptions about risk preferences.

where r is the utility discount rate ($r>0$); and u is a nonlinear utility function[2]. The interior solution is where the sums of discounted marginal utilities for perennial and conventional crop production are equal.

4.2. Uncertainty

Agricultural production is a risky endeavor because of the uncertainty in prices, yields, and costs. Farmer's risk preferences play an important role in the decision process. Assuming no liquidity constraints, the farmer's expected utility objective function is:

$$\max_{a_p \geq 0} \quad E\left[u\left(\sum_{t=0}^{T}\frac{1}{(1+r)^t}\pi_t\left(a_p,\tilde{p}_t,\tilde{y}_t,\tilde{v}_t,\tilde{f}_t\right)-C\right)\right] \quad s.t. \quad a_p \leq A \tag{4}$$

where ~ indicates a random variable; E is the expectation operator; and u is a concave intertemporal utility function. Concavity of the utility function implies that farmers are risk averse. The randomness of these variables includes the probability that subsidies can change overtime. Subsidies (e.g. the Biomass Crop Assistance Program) in the emerging bioenergy market will likely be part of perennial crop production in the short term. The interior solution is the perennial acreage where expected marginal utility for perennial and conventional crop production are equal.

4.3. Farm Households

Up to this point, we have treated the decision as simply a farm production decision, which is likely the case for farms operated by a firm. However, farms that are operated by households (consumers) will have additional considerations in their decision process. The objective of the farm household is:

$$\max_{c \geq 0} \quad \sum_{t=0}^{T}\frac{1}{(1+r)^t}E\left[u\left(\tilde{c}_t\right)\right] \quad s.t \quad \tilde{c}_t = \tilde{\pi}_t + w_t \tag{5}$$

where c is the quantity of a numeraire good; and w is non-farm income.

4.4. Intertemporal Choices, Liquidity Constraints, Uncertainty, and Farm Household

In the previous sections we have highlighted the implications of relaxing certain assumptions on the conceptual model of the farmer's decision process. If we combine all of the relaxed assumption into a single decision model the objective function of the farmer is:

[2] The utility function can be either concave or convex as we have made no assumptions about risk preferences.

$$\max_{a_p \geq 0} \quad \sum_{t=0}^{T} \frac{1}{(1+r)^t} E\left[u\left(\tilde{\pi}_t + w_t - C\right)\right] \quad s.t. \quad a_p \leq A \tag{6}$$

4.5. Optimization

In each of the previous sections we discussed characteristics of the optimal solution. Here we explicitly derive the first order conditions for our general model. We use the method of Lagrange multipliers to find the maximum subject to a constraint. The Lagrange function is:

$$L = \sum_{t=0}^{T} \frac{1}{(1+r)^t} E\left[u\left(\tilde{\pi}_t + w_t - C\right)\right] + \lambda\left(a_p \leq A\right) \tag{7}$$

where λ is the Lagrange multiplier. The set of first order conditions (FOCs) are:

$$\frac{\partial L}{\partial a_p} = \sum_{t=0}^{T} \frac{1}{(1+r)^t} E\left[u'\left(\tilde{\pi}_t\left(a_p *\right) + w_t - C\right)\left(\left(\tilde{p}_p \tilde{y}_p - \tilde{v}_p\right) - \left(\tilde{p}_c \tilde{y}_c - \tilde{v}_c\right)\right)\right] + \lambda * \leq 0, \frac{\partial L}{\partial a_p} a_p * = 0, a_p * \geq 0 \tag{8}$$

$$\frac{\partial L}{\partial \lambda *} = a_p * - A \leq 0, \frac{\partial L}{\partial \lambda *} \lambda * = 0, \lambda * \geq 0 \tag{9}$$

where a_p* is the optimal perennial acreage; and $\lambda*$ is the optimal rate of change of the objective function. The optimal acreage can be 0 or A which are both corner solutions that must be considered.

4.6. Acreage Interior Solution

In this section we examine the optimal solution for the perennial acreage assuming an interior solution, $0 < a_p* < A$. If a_p* is an interior solution then equation (9) implies that $l*=0$ and equation **Error! Reference source not found.** holds with equality. At the optimal acreage the following condition must hold:

$$\sum_{t=0}^{T*} \frac{1}{(1+r)^t} E\left[u'\left(\bar{a}_p *\right)\left(\tilde{p}_p \tilde{y}_p - \tilde{v}_p\right)\right] = \sum_{t=0}^{T*} \frac{1}{(1+r)^t} E\left[u'\left(\bar{a}_p *\right)\left(\tilde{p}_p \tilde{y}_p - \tilde{v}_p\right)\right]. \tag{10}$$

where $\bar{a}_p *$ is the interior perennial acreage solution. The sums of the discounted expected marginal utility of perennial and conventional crop production from the present to the optimal rotation period must be equal. At the margin there is no additional utility that can be gained from increasing or decreasing the perennial acreage.

4.7. Acreage Corner Solutions

There are two corner solutions to this optimization problem. The perennial acreage can be 0 or be limited by the constraint to A. We first look at the case when corner solution is zero. From equation (9) if $a_p*=0$ then $\lambda*=0$ and the inequality of equation **Error! Reference source not found.** hold with inequality. Assuming that the sums of the marginal utilities are positive the following condition must hold:

$$\sum_{t=0}^{T*}\frac{1}{\left(1+r\right)^{t}}E\left[u'\left(\tilde{\pi}_{t}\left(0\right)\right)\left(\tilde{p}_{p}\tilde{y}_{p}-\tilde{v}_{p}\right)\right]\leq\sum_{t=0}^{T*}\frac{1}{\left(1+r\right)^{t}}E\left[u'\left(\tilde{\pi}_{t}\left(0\right)\right)\left(\tilde{p}_{c}\tilde{y}_{c}-\tilde{v}_{c}\right)\right] \tag{11}$$

where the marginal utility is evaluated at $a_p*=0$. The sums of the discounted expected marginal utility of perennial crop production from the present to the optimal rotation period evaluated at 0 must be less than the sums of the discounted expected marginal utility of conventional crop production from the present to the optimal rotation period evaluated at 0. At the margin there is no additional utility that can be gain from producing perennial crops.

We now look at the case were the corner solution is the total acreage A and the constraint is binding. From equation (9) if $a_p*=\mathrm{A}$ then $\lambda*\geq 0$ and equation **Error! Reference source not found.** holds with equality. Assuming that the sums of the marginal utilities are positive the following condition must hold:

$$\sum_{t=0}^{T*}\frac{1}{\left(1+r\right)^{t}}E\left[u'\left(\tilde{\pi}_{t}\left(A\right)\right)\left(\tilde{p}_{p}\tilde{y}_{p}-\tilde{v}_{p}\right)\right]\geq\sum_{t=0}^{T*}\frac{1}{\left(1+r\right)^{t}}E\left[u'\left(\tilde{\pi}_{t}\left(A\right)\right)\left(\tilde{p}_{c}\tilde{y}_{c}-\tilde{v}_{c}\right)\right] \tag{12}$$

where the marginal utility is evaluated at $a_p*=\mathrm{A}$. The sums of the discounted expected marginal utility of perennial crop production from the present to the optimal rotation period evaluated at 0 must be greater than the sums of the discounted expected marginal utility of conventional crop production from the present to the optimal rotation period evaluated at 0. At the margin there is no additional utility that can be gain from producing conventional crops.

Optimal Solution

In the previous two sections we outlined the conditions that must hold for the interior solution and the two corner solutions. We are most interested in the comparison of the expected utilities when the acreage is zero and when it is greater than zero. Define a_p* is the perennial acreage that solves the following maximization:

$$\max\left\{\overbrace{\sum_{t=0}^{T}\frac{1}{\left(1+r\right)^{t}}E\left[u\left(\tilde{\pi}_{t}\left(\bar{a}_{p}*\right)+w_{t}\right)\right]}^{a},\overbrace{\sum_{t=0}^{T}\frac{1}{\left(1+r\right)^{t}}E\left[u\left(\tilde{\pi}_{t}\left(A\right)+w_{t}\right)\right]}^{b}\right\} \tag{13}$$

where term a is the net present of expected utility for the interior solution and term b is the net present value of expected utility for the corner solution where only perennial crops are produced. This is the optimal solution conditional on $a_p>0$. We can compare this to the other corner solution where no perennial acreage is produced. A farmer will grow perennial crops if the following condition holds:

$$\sum_{t=0}^{T^*} \frac{1}{(1+r)^t} E\left[u\left(\tilde{\pi}_t\left(a_p^*, s_p=1\right)+w_t\right)\right] \geq \sum_{t=0}^{T^*} \frac{1}{(1+r)^t} E\left[u\left(\tilde{\pi}_t\left(0, s_p=0\right)+w_t\right)\right] \qquad (14)$$

where s_p is the indicator function that equals one when $a_p>0$ and zero when $a_p=0$. If the net present value of expected utility evaluated at the optimal perennial acreage greater than zero and a fixed cost of perennial production is greater than the net present value of expected utility evaluated at $a_p=0$ and no fixed cost of perennial production.

4.8. Fixed Income Expectations

Bioenergy is an emerging market in which agricultural landowners have little information on the agronomics, costs, and yields from perennial bioenergy crop production. In addition returns from current crop production are variable from year-to-year. These can be controlled for in a hypothetical situation by setting the expected per acre returns from perennial crop production relative to current crop production returns. The difference in returns per acre is I.

$$\frac{E\left[\pi_t^p\right]}{a^p} = \frac{E\left[\pi_t^p\right]}{A} + I \qquad (15)$$

5. Data

5.1. Survey

The survey is targeted at agricultural landowners in the lower Minnesota River Valley. The counties include: Blue Earth, Brown, Carver, Le Sueur, Martin, Nicollet, Scott, Sibley, and Watonwan. This population was chosen for two major reasons: these counties have a majority of their land in the lower Minnesota River watershed and are nearest to the Koda Energy bioheat and power plant and a site for a potential biomass plant (Madelia). Most of the agricultural land in this region is used to grow corn and soybeans.

Addresses for the agricultural landowners were obtained through the county tax assessor's office. This included records for parcels zoned for agriculture. Parcels with acreage less than twenty acres were not included in the final study population. This was to prevent land zoned for agriculture but used for other purposes, such as a homestead, from being included in the population. This does not necessarily exclude these landowners because they may own other parcels larger than 20 acres. The mailing or tax address was used as the address for contact. Duplicate addresses were deleted which significantly reduced the number of addresses for the counties. After aggregation of all county lists duplicates were deleted again. This left us with a final study population of 13,850 agricultural landowners in the nine counties.

5.2. Sample

After determining the study population the next step was to randomly draw a sample size that was large enough for the anticipated results to be statistically significant. N_s is the completed sample size, N_p is the size of the population, p is the proportion of the population expected to choose one of the two response categories, B is the margin of error, C is the Z-score associated with the confidence level.

Table 1: Minimum Sample Size

$$N_s = \frac{(N_p)p(1-p)}{(N_p - 1)(B/C)^2 + p(1-p)}$$

N_p	p	B	C
13,850	0.50	+/- 5%	1.96 (95%)

Given these desired parameters and our sample size the completed sample size needs to be at least 375 agricultural landowners (Dillman, D., & Smyth, J., 2008). Given that survey response rate can vary widely and depend on the successful design of the survey, 1000 surveys were mailed anticipating at least a 40% response rate.

5.3. Survey Instrument

The survey was carefully constructed to be visually appealing, clear and understandable. As an interdisciplinary study the survey designers had many questions that they were interested in asking. Using the focus groups and the literature these questions were narrowed down. The final survey was eight pages long with a minimum of 95 questions that the respondents were asked to answer. Therefore this is a relatively long survey and it is estimated it took respondents 15-30 minutes to complete. The first section of the survey asked about the acreage owned, leased, and farmed, the uses of the land, and the future plans on the land. Respondents were also asked what their awareness was of perennial grasses and short rotation woody crops (SRWC) before receiving this survey.

Then the respondents were provided some fast facts about perennial grasses and SRWC including the benefits of perennial crops compared to annual row cropping. Following this the respondents were asked questions, on a four-point scale, about their attitudes and perceptions about conservation, perennial bioenergy crops, and US energy profile. They were also asked that, if growing these crops was financially competitive with their other land use options, what their current level of interest was. The next section asked the respondents to indicate the degree, on a four-point scale, to which potential barriers would limit their willingness to grow perennial crops for energy. This was followed up with similar questions that were specific just to SRWC. The next question asked respondents to rank in descending order five potential financial agreements for perennial grasses and SRWC separately. These financial agreement questions varied in terms of the level of risk to the landowner.

In questions 13 and 14 the respondents were asked about their willingness to grow perennial grasses or SRWC given a randomly generated relative net income. In order to minimize bias, closed-ended pure dichotomous choice questions were used. These questions were asked near the end of the survey to give as much information to the respondents before they answered them. The first question asked the farmer's willingness to grow perennial grasses and the second asked their willingness to grow SRWC. Each question included one of eight relative net incomes. The set of relevant net incomes were determined from a pretest survey and included net incomes both lower and higher then their current net income and different ranges for grasses and SRWC. In order to limit the influence of the two questions on each other sixty-four versions of the survey, one of each possible combination of the net income amounts were randomly distributed across the sample population. Following these questions, the respondents were also asked what type of farmland they would target for establishment.

The second to last section of questions was demographic information about the respondent and the household. This section was put at the end of the survey because the respondent likely has survey fatigue and these questions are relatively easier for respondents to answer because of their familiarity with them. Finally the respondents were asked if they would be willing to participate in in-person and/or phone interviews and an open ended question asking if there was anything else that they would like to share.

5.4. Mail Survey Implementation

The survey used the standard five contact Dillman mail survey method (Dillman 2009). The survey was conducted in late 2010 and early 2011. First, a pre-notice letter was mailed to the respondents approximately one week before the mailing of the first questionnaire to prepare respondents to receive the survey. The survey was mailed with a cover letter explaining the purpose of the survey and a prepaid envelope to return the survey. One week later a reminder postcard was sent that reiterated the importance of filling out the survey and reminded respondents to return it. When the number of returned surveys slowed to 0-2 per day, approximately 4 weeks after the first survey, a second replacement survey was sent out. This survey was mailed in a different size and color envelope from the first survey and only to addresses that had not responded already. The final contact was made with another reminder postcard about one week after the last survey was mailed out.

6. Methods

Our conceptual model is an expected utility framework that incorporates intertemporal choices, liquidity constraints, uncertainty, and the farm as a household. Using a hypothetical stated choice experiment where we fix the relative expected net income per acre to their current net income per acre we are able to indirectly estimate parameters of the respondents utility function even without information on prices, yields & costs. The estimation is indirect because we do not observe directly intertemporal preferences, liquidity constraints and risk aversion. However, parameters of the observable proxy variables that are correlated with these underlying unobservables can be estimated. Notions of liquidity constraints and risk aversion can be represented in the estimation by a nonlinear estimation function. In addition to parameter estimation, because of the potential for corner solutions, we can estimate the two decision processes to understand the differences.

6.1. Econometrics of WTS

The willingness to supply questions in the landowner survey were designed as closed-ended pure dichotomous choice questions. Asking questions in this way attempts to avoid leading the respondent so as to minimize biases. Dichotomous choice questions necessitate the use of a discrete choice statistical analysis (e.g., probit, logit). Using a random utility model framework one can derive the probability the respondent will answer yes to the question given assumptions about the underlying utility function and the distribution of the error term (Wooldridge, 2002). Let u be the utility for the respondent,

$$u(\boldsymbol{\pi}, w, x, \boldsymbol{\varepsilon}) = \sum_{t=0}^{T} \frac{1}{(1+r)^t} E\left[u\left(\tilde{\boldsymbol{\pi}}_t + w_t - C\right)\right] \quad (16)$$

where $u(\boldsymbol{\pi},w,x,\boldsymbol{\varepsilon})$ is a simplification the utility function in equation **Error! Reference source not found.**; $\boldsymbol{\pi}$ is the profit; w is the nonfarm income; x is the vector of agricultural landowner characteristics and represents the underlying heterogeneity; and $\boldsymbol{\varepsilon}$ is the random component. The WTS questions ask respondents if they would grow perennial crops given a stated expected net income amount relative to current production. The respondent will answer yes (see section 0 for details) to the question if:

$$u^1\left(\boldsymbol{\pi}^1\left(a_p > 0\right) + \hat{\boldsymbol{\pi}}, w, x, \boldsymbol{\varepsilon}^1\right) > u^0\left(\boldsymbol{\pi}^0\left(a_p = 0\right), w, x, \boldsymbol{\varepsilon}^0\right) \quad (17)$$

The utility is unobservable but the dichotomous choice is

$$\Pr\left(a>0 \middle| w,x,\pi\right)=\Pr\left(u^1\left(\pi^1+\hat{\pi},w,x,\varepsilon^1\right)>u^0\left(\pi^0,w,x,\varepsilon^0\right)\right). \tag{18}$$

In order to empirically estimate the probability one must move on from this general form. The first assumption is that the error term is additively separable.

$$u\left(\pi,w,x,\varepsilon\right)=v\left(\pi,w,x\right)+\varepsilon \tag{19}$$

Then the probability function becomes,

$$\Pr\left(a>0 \middle| w,x,\pi\right)=\Pr\left(v^1\left(\pi^1+\hat{\pi},w,x\right)+\varepsilon^1>v^0\left(\pi^0+\hat{\pi},w,x\right)+\varepsilon^0\right) \tag{20}$$

Because the error terms are unobservable we have,

$$\varepsilon^0-\varepsilon^1=\varepsilon \tag{21}$$

$$\Pr\left(a>0 \middle| w,x,\pi\right)=\Pr\left(v^1\left(\pi^1+\hat{\pi},w,x\right)-v^0\left(\pi^0+\hat{\pi},w,x\right)>\varepsilon\right) \tag{22}$$

So that the probability of the respondent answering yes to the question is equal to the probability that the utility under the new cropping system minus the utility under the current cropping system is greater then the error term. In order to proceed, an assumption on the functional form of the utility function must be made. To estimate this probability a distribution for the error term must be specified. Assuming a normal distribution for the error term results in the probit model.

$$\Pr\left(a>0 \middle| w,x,\pi\right)=\Pr\left(\frac{x\alpha+\hat{\pi}+\pi\beta+w\eta}{\sigma}>\frac{\varepsilon}{\sigma}\right)=\Phi\left(\frac{x\alpha+\hat{\pi}+\pi\beta+w\eta}{\sigma}\right) \quad \frac{\varepsilon}{\sigma}\sim N\left(0,1\right) \tag{23}$$

6.2. Econometrics of Acreage

In addition to the dichotomous choice is the respondents answer yes to the willingness to supply question they are asked a follow up question on the quantity of acreage they would use for perennial crop production given the relative expected net incomes per acre. If the respondents answer yes then equation (17) must hold with strict inequality and the interior solution or the corner solution where $a=A$ has a higher sum of expected marginal utility. Then the linear estimation of the acreage is,

$$a=x\alpha+\hat{\pi}\beta^1+\pi\beta+w\eta+\varepsilon. \tag{24}$$

6.3. Corner Solution Models

Acreage decisions are a corner solution response in which acreage is continuously distributed above zero but has a focal point at zero with positive probability

(Wooldridge 2010). Corner solution models are uniquely adapted to account for this discrete feature.

Type I Tobit Model

Modeling the acreage decision can be done using a single decision model. The type I Tobit model follows from the assumptions,

$$a = \max\left(0, x\alpha + \hat{\pi}\beta^1 + \pi\beta + \mu\right) \quad \mu|x \approx \text{Normal}\left(0, \sigma^2\right) \tag{25}$$

The Tobit model restricts the explanatory variables and the coefficients to be the same for the two decision processes.

$$E\left[a_i | x_i, \pi_i\right] = \Phi\left(x_i\alpha + \hat{\pi}_i\beta^1 + \pi_i\beta\right)\left\{x_i\alpha + \hat{\pi}_i\beta^1 + \pi_i\beta + \sigma\lambda_i\left(\frac{x_i\alpha + \hat{\pi}_i\beta^1 + \pi_i\beta}{\sigma}\right)\right\} \tag{26}$$

While restrictive the partial derivatives of the type I Tobit model allows for a simple interpretation of the partial effect of the explanatory variables.

$$\frac{\partial E\left(a|x\right)}{\partial x_j} = \Phi\left(\frac{x\beta}{\sigma}\right)\beta_j \tag{27}$$

The partial effect of each explanatory variable is the estimated coefficient multiplied by a scale factor equal to the normal cumulative distribution function evaluated at $x\beta$.

Two-Part (Hurdle) Models

As mentioned in the previous section the type I Tobit model imposes restrictions on the explanatory variables and coefficients. Two-part models are more flexible by allowing separate mechanisms to model the two decision processes: participate in the perennial bioenergy market and the quantity of acreage to grow. This allows the coefficients to vary across the two decision parts. Additionally the vector of explanatory variables for the two decision parts can also be different. The two part models follow from the assumption,

$$a = s \cdot f\left(x\alpha + \hat{\pi}\beta^1 + \pi\beta + \mu\right) \tag{28}$$

where s is a binary variable that can be zero or one and determines whether the acreage is zero or strictly positive. The two-steps refer to the two decisions processes that are modeled independently. The log-likelihood function used in the maximum likelihood estimation is additively separable allowing estimation of the freely varying parameters independently (Wooldridge 2010). The first step is to estimate the probit model for the participation decision assuming a normal distribution. The second step models the acreage decision based on the chosen functional form and distribution of the error term. There are several options for the second step, outlined below.

$$E\left[a_i|x_i,\pi_i\right]=\Phi\left(x_{1i}\alpha+\hat{\pi}_i\beta^1+\pi_i\beta\right)f\left(x_{2i}\varphi,\hat{\pi}_i\gamma^1,\pi_i\gamma\right) \tag{29}$$

Truncated normal

The truncated normal hurdle model assumes a normal distribution that is truncated, in this case at $-\left(x\varphi+\hat{\pi}\gamma^1+\pi\gamma\right)$. This limits the prediction of the model to non-negative values for acreage. The first step is the standard probit model and the second step is the truncated regression.

$$E\left[a_i|x_i,\pi_i\right]=\Phi\left(x_{1i}\alpha+\hat{\pi}_i\beta^1+\pi_i\beta\right)\left\{x_{2i}\varphi+\hat{\pi}_i\gamma^1+\pi_i\gamma+\sigma\lambda_i\left(\frac{x_{2i}\varphi+\hat{\pi}_i\gamma^1+\pi_i\gamma}{\sigma}\right)\right\} \tag{30}$$

This reduces to the type I Tobit model when $x_1=x_2$ and $\beta=\frac{\gamma}{\sigma},\alpha=\varphi$.

Log-normal

The lognormal hurdle model assumes that the functional form for the second step is the exponential function. Assuming the error term is normally distributed then the second step follows a lognormal distribution;

$$E\left[a_i|x_i,\pi_i\right]=\Phi\left(x_{1i}\alpha+\hat{\pi}_i\beta^1+\pi_i\beta\right)\exp\left\{x_{2i}\varphi+\hat{\pi}_i\gamma^1+\pi_i\gamma+\frac{\sigma^2}{2}\right\} \tag{31}$$

Exponential type II Tobit model

The independence of the two steps in the above models is conditional on the independence of the error terms in each step. This assumption may be violated in the case where unobserved factors affect both the decisions. The exponential type II Tobit model allows the error terms to be correlated.

$$E\left[a_i|x_i,\pi_i\right]=\Phi\left(x_{1i}\alpha+\hat{\pi}_i\beta^1+\pi_i\beta+\eta\right)\exp\left\{x_{2i}\varphi+\hat{\pi}_i\gamma^1+\pi_i\gamma+\frac{\sigma^2}{2}\right\} \tag{32}$$

The first step includes the regression coefficient (η) of the error term from the second step on the first step. The correlation between the error terms is $\rho=\eta/\sigma$ and can be tested against the hypothesis that there is no correlation $H_0:\rho=0$. In this way, we can identify if there are unobserved factors that influence both decision processes or if, contingent on the vector of explanatory variables, the two decision processes appear to be independent.

7. Results and Discussion

7.1. Survey Response

The survey had a relatively high response rate given the length of the survey. Using current tax records for mailing address kept the undeliverable surveys (2) to a minimum. Five hundred forty eight surveys were returned with at least a partial response giving a final response rate of just under 50%. This is comparable (56% response rate) to the 2007 study of Michigan's corn and soybean farmer's willingness to adopt environmental practices by Jolejole et al. and significantly higher than Jensen et al. (2007) and their survey of the willingness for Tennessee farmers to grow switchgrass (24% response rate).

7.2. Descriptive Statistics

Willingness to Supply

The willingness to supply questions asked the respondents if they would grow perennial bioenergy crops if their annual net farm income were a randomly selected amount greater than their current net farm income per acre. The randomly selected amount ranged from -$100 to $250 for perennial grasses and -$50 to $300 for SRWC at $50 increments. Some (17%) respondents were willing to supply perennial grasses at negative amounts. The willingness to supply jumped 45% at the net income amount ($0) equal to their current net income. The percentage of respondents and the acreage was non-decreasing in relative net incomes. Almost no respondents (4%) were willing to supply SRWC at net incomes less than their current net income. The percentage of respondents and the acreage was non-decreasing in relative net incomes for SRWC as well. At all amounts the percentage of respondents willing to supply perennials was lower for SRWC as compared to grasses.

Respondents were asked if they were to grow perennial energy crops what type of farmland would they target for establishment. Almost half (44%) of the respondents indicated that they would target poor quality soil. Only some (7%) respondents indicated that they would target their most productive land for establishment.

7.3. Willingness to Supply & Acreage Supplied

The data is evaluated using corner solution models to understand the significance and direction of the explanatory variables on the farmer's willingness to supply. Both the type 1 Tobit model and two-step hurdle models were evaluated. The two-step models provided a better fit to the data than the type 1 Tobit model in which the two decisions are modeled together. The willingness to supply (part 1) was modeled as a probit. In part 2 the lognormal model provided a better fit for the data than the truncated regression. With an exponential relationship (lognormal) a change in the explanatory variables is associated with a percentage change in acreage. The exponential type II model has a larger log likelihood because the lognormal hurdle model in nested within it. However, the value for ρ (correlation between the error terms) is not significantly different from zero. Therefore it is unlikely that there are omitted factors that influence both decision processes.

Willingness to Supply Perennial Grasses

The model that best fit the data for the two parts of the decision contained different vectors for each part of the decision processes. In addition to the relative net income amounts the willingness to supply (part 1, probit model) was also correlated with interest, attitudes, barrier perception, and demographics. Interest was positively correlated (1.33) and highly significant (1% level) which we would expect. The perception and attitude variables were both positively and negatively correlated. This is interesting because one would expect the correlation to be positive. The more strongly you agree with conservation or alternative energy policies the more likely you would be to grow crops that provided these benefits. *Concerned with the quality of their farm soil* and if they were to *grow perennial energy crops they would be perceived as a land steward by their peers* was negatively correlated with willingness to supply. A possible explanation in addition to omitted variable bias is that those agricultural landowners who already feel they are concerned about soil quality don't feel the need to grow perennials to conserve it. Landowners who indicate a strong agreement of being perceived as a land steward may be more influenced by their peers. Not controlling for an omitted variable such as peer influence may have a negative bias on being perceived as a land steward. Those who are more influenced by their peers may be less likely to grow nonconventional crops.

We would expect the perceived barriers to be positively correlated with willingness to supply. The lesser degree to which landowner perceives a potential barrier as limiting, the greater should be their willingness to supply. This was the case for lack of access to equipment and loss of loan eligibility. However, one potential barrier, lack of financial assistance was negatively correlated.

Male respondents were more willing to supply, as were households that did not have someone working off the farm. Respondents who described themselves as part-time farmers were also more willing to supply. This may be due to the relatively lower workload of perennial energy crops as compared to conventional crops. Household income was positively correlated with willingness to supply but farm income was not correlated. This may suggest that the willingness to supply is a household level decision.

Perennial Grass Acreage Supply

A different set of explanatory variables best fit the lognormal acreage supply model. Broad categories not included in the part one probit model were land tenure, future land use plans, and conservation programs and practices. Non-negative net incomes were positively correlated with acreage supplied suggesting a discrete acreage jump at net incomes equal to current net incomes. However, the net income amount was not significant suggesting no increase in acreage supplied above zero.

Agricultural landowners who owned more acreage and those who leased out more acreage indicated they would supply more perennial bioenergy crop acreage. Landowners who were more likely to use their land for recreation indicated they would supply less perennial acreage. Individuals that plan to use their land for recreation may have less interest in working lands. Landowners who already had plans for a different crop indicated they would supply more acreage.

As with willingness to supply, acreage supplied should also be positively correlated with the degree to which landowners perceive barriers as less limiting. This was not the case with the one significant variable risk involved with growing new crops. A possible explanation is that those that do see the risk involved with a new crop as a limit but are willing to take the risk will grow more acreage to further diversify their risk of other crops.

Respondents who lived farther from their land indicated they would supply more acreage. The landowners who are farther away may have an interest in making the costly trip more worthwhile by growing more acreage. In contrast to the willingness to supply model household income was not significant while farm income was significant and positive. This may suggest that the acreage supplied is a farm level decision.

Willingness to Supply Short Rotation Woody Crops

Similarly to the willingness to supply perennial grasses model the willingness to supply SRWC lognormal hurdle model provided that best fit. Non-negative net income amounts were significant indicating a discrete jump in willingness to supply at relative net incomes of $0. The net income amount was not significant at the 10% level but was positively significant at a 12% level. Willingness to supply SRWC was correlated with land tenure variables which is a difference from the perennial grasses model. The more acres that the respondents rented from others the more willing they were to grow SRWC but the more acres they farmed the less likely they were willing to grow SRWC.

Landowners involved in government conservation programs that conserve natural resources while farming such as the Conservation Security Program where also more willing to supply SRWC. In terms of future landuse plans all significant variables were positively correlated with willingness to supply SRWC. This includes future plans such as selling land for non-agricultural uses, using land for recreation, and diversifying the current uses of my land. This suggests that these future plans are consistent with having trees on the land. Respondents who agreed that it is important to provide habitat for wildlife on their land were more willing to grow SRWC. This is consistent with the positive correlation with future plans for recreation and suggests that landowners see SRWC providing better habitat for wildlife and recreation opportunities than perennial grasses.

Potential barriers to growing SRWC were expected to be positive. Respondents who thought having trees roots and stumps in tillable land was less limiting were more willing to grow SRWC. However, those that identified a lack of renter or contract service provider as less limiting were less likely to grow SRWC.

In contrast to perennial grasses, agricultural landowners who would target poorly drained soils for perennials where less willing to grow SRWC. However, those who would target sloped land where more willing. This gives an indication about where farmers would target establishment of each category of perennials. As with perennial grasses, part-time farmers were more willing to grow SRWC.

Short Rotation Woody Crops Acreage Supply

As with the perennial grass model the vector of explanatory variables for the SRWC acreage model was a different set from the willingness to supply model. The net income amount was positively correlated with SRWC acreage. Respondents who owned more land were willing to grow more acreage of SRWC.

Landowners who were more aware of SRWC before receiving the survey indicated that they would grow a smaller acreage of SRWC. This suggests that information received prior to the survey lowered the acreage they would grow.

Respondents who identified a lack of information about growing crop as less limiting were more likely to grow the crop. Similar to the willingness to supply model, the lack of renter or contract services provider was negatively correlated with acreage.

While part-time farmers were more willing to grow SRWC, full-time non-retired farmers indicated they would grow less SRWC acreage. In contrast to perennial grasses, both household income and farm income were positively correlated with SRWC acreage.

7.4. Farm Level Acreage Supply Model

Multiplicatively combing these two parts results in a farm level supply model for perennial crops. This supply model was evaluated in the range of relative net incomes used in the study and the means of the other explanatory variables (Figure 1). There is a relatively low supply of acreage at negative relative net incomes. The discrete jump when the difference in relative net incomes is zero is approximately 32 acres for perennial grasses and approximately 13 acres for SRWC. The acreage supplied is increasing with net income amounts but higher always higher for grasses than SRWC.

8. Summary and Conclusion

The results of this survey provide insights into the decision processes of southern Minnesota agricultural landowners that will guide decisions in the emerging perennial bioenergy markets. There is a strong indication that landowners' decision processes are different for perennial grasses and SRWC, with farmers more willing to supply perennial grasses. Returns from SRWC would need to be higher than grasses for agricultural landowners to be just as willing to grow SRWC.

The decision processes for both grasses and SRWC most likely follow a two-part process. The first decision is whether to grow perennial crops. This decision appears to be a household level decision that is influenced by attitudes and perceptions, respondent gender, work status, and target farmland among other things. The second decision, once the landowner has decided to grow perennial crops, is the acreage. This decision appears to be a farm level decision that is influenced by acres owned and leased to others, future land use plans, and current conservation practices and programs. The lack of correlation between the error terms in the two decision processes makes it unlikely that there is an omitted variable that significantly correlated with both decisions.

Landowners who ranked highly the financial agreement in which the landowner would receive an annual payment for a 10 year easement; planting, maintenance, and harvest would be the responsibility of a contract service provider; and the landowner would be paid for biomass crop upon delivery were more willing to grow perennial crops.

Farmland targeted for perennial energy crops was different for perennial grasses and SRWC. Landowners who were willing to grow grasses were more likely to target poorly drained soils for establishment. Those willing to grow SRWC were more likely to target sloped land but less likely to target poor quality soil.

This analysis is a static look at the current willingness of agricultural landowners to supply perennial bioenergy crops. As the emerging market evolves and becomes well established the decision processes are likely to change including the perceptions of risk. However, this market's current underdevelopment is a big hurdle to overcome.

Understanding the two part decision process for different categories of perennial bioenergy crops is important for designing policy to seed the market. Policy designers must understand the underlying factors that affect the separate decision processes based on whether they would like to encourage more agricultural landowners to enter the market, encourage more acreage grown by current landowners in the market, or both.

9. Appendix

Table 2: Acreage & Land-use

	acres|acres>0		acres>0	
	mean	**± (95%)**	**%**	**± (95%)**
Land I Own	227	*28*	1.00	*.00*
Land I lease/sharecrop **TO** others	185	*44*	0.50	*.04*
Land I rent/sharecrop **FROM** other	394	*95*	0.22	*.04*
Total Land I Farm	369	*55*	0.54	*.04*
Corn	157	*20*	0.89	*.03*
Soybean	140	*17*	0.81	*.04*
Wetland	21	*6*	0.17	*.03*
Alfalfa	32	*7*	0.17	*.03*
Wildlife habitat	33	*10*	0.17	*.03*
Other	32	*11*	0.13	*.03*
Hay-not including alfafa	15	*3*	0.12	*.03*
Pasture livestock	27	*9*	0.12	*.03*
Recreation-such as hunting, bird watching	32	*9*	0.09	*.03*
Wheat, oats, and other small grains	26	*7*	0.08	*.02*
Native prairie	30	*9*	0.07	*.02*
Confined livestock	14	*11*	0.06	*.02*
Vegetables	66	*36*	0.04	*.02*
Orchards	4	*2*	0.02	*.01*
Sugar beets	143	*66*	0.01	*.01*
Short rotation woody crops	7	*6*	0.01	*.01*

Table 3: Conservation Practices

	Yes		No		Don't Know	
	%	**±**	**%**	**±**	**%**	**±**
Soil conservation practice such as no-till/low-till, direct seeding, nutrient management	0.45	*.05*	0.42	*.05*	0.13	*.03*
Conservation easement such as Conservation Reserve Program (CRP)	0.36	*.04*	0.58	*.04*	0.06	*.02*
Government conservation program that conserves natural resources while farming such as the Conservation Security Program (CSP)	0.09	*.03*	0.78	*.04*	0.12	*.03*

Table 4: Future Land-use

	mean	±	1 Highly Unlikel y	2 Somewhat Unlikely	3 Somewhat Likely	4 Highly Likely	Don't Know
I will maintain the current use(s) of my land	3.6	*.08*	.07	.02	.14	.70	.07
Land will be inherited by family member(s)	3.2	*.10*	.14	.07	.20	.53	.06
Land will be rented	3.0	*.11*	.20	.07	.17	.49	.06
Land will be operated by family member(s)	2.6	*.12*	.36	.08	.12	.39	.05
I will grow a different crop	1.9	*.10*	.42	.21	.16	.07	.14
Land will be sold for agricultural use	1.8	*.11*	.51	.12	.11	.12	.14
I will diversify the current use(s) of my land	1.7	*.09*	.49	.17	.13	.06	.15
Land will be used for recreation	1.6	*.10*	.67	.06	.09	.11	.07
Land will be taken out of production and used for conservation	1.5	*.08*	.65	.15	.06	.05	.09
Land will be sold for a non-agricultural use	1.4	*.08*	.70	.10	.05	.04	.12
I will reduce the current use(s) of my land	1.3	*.07*	.68	.14	.03	.03	.12
I will cease to use my land	1.3	*.08*	.77	.06	.03	.06	.08

Table 5: Interest & Awareness

	mean	±	1 No	2 Little	3 Some	4 High
Awareness			%	%	%	%
Perennial Grasses	2.3	*.09*	.26	.23	.42	.09
Trees	2.2	*.09*	.33	.26	.33	.09
Interest						
Perennial Grasses	2.7	*.09*	.14	.20	.45	.20
Trees	2.4	*.09*	.25	.26	.34	.15

Table 6: Attitudes

	mean	±	1 Strongly Disagree	2 Somewhat Disagree	3 Somewhat Agree	4 Strongly Agree	Don't Know
I have a responsibility to conserve the land for use by future generations	3.7	*.05*	.01	.02	.19	.76	.03
The United States should increase domestic sources of	3.4	*.07*	.03	.05	.34	.50	.08

renewable energy							
I am concerned with the quality of my farm soil	3.3	*.09*	.10	.07	.23	.55	.05
I am concerned with the effect my land has on water quality	3.2	*.09*	.10	.09	.28	.49	.04
Farmland should be used to increase the United States' energy independence	3.2	*.08*	.06	.10	.38	.37	.09
Growing perennial energy crops could provide wildlife habitat on my land	3.2	*.07*	.04	.10	.45	.31	.10
I believe it is important to provide habitat for wildlife on my land	3.1	*.08*	.08	.10	.38	.39	.05
Growing perennial energy crops could improve water quality in my area	3.0	*.08*	.04	.13	.42	.23	.18
If I were to grow perennial energy crops I would be perceived as a land steward by my peers	2.7	*.08*	.06	.17	.40	.10	.27
Diversifying my production will reduce financial risk on my farm	2.5	*.09*	.12	.23	.30	.12	.23

Table 7: Perceived Barriers

	mean	**±**	**1 Highly Limiting**	**2 Moderately Limiting**	**3 Slightly Limiting**	**4 Not Limiting**	**Don't Know**
Opinion of my family and friends	2.9	*.11*	.12	.18	.20	.36	.15
Spending time to learn about a different system	2.6	*.09*	.13	.23	.31	.19	.13
Necessity to learn new skills	2.5	*.10*	.18	.26	.26	.17	.13
Loss of bank loan eligibility for converted acres	2.4	*.12*	.27	.21	.13	.22	.18
Working with government technical assistance	2.3	*.10*	.22	.26	.25	.13	.15
Having to complete paperwork involved with program	2.2	*.10*	.29	.24	.23	.12	.12
Loss of base acreage eligible for government subsidies	2.2	*.11*	.32	.20	.13	.17	.17
Having to sign a contract with an energy producer	2.1	*.10*	.27	.29	.20	.10	.14
Current renter not interested	2.1	*.13*	.32	.13	.09	.15	.32
Having to sign a contract with the government	2.1	*.10*	.35	.23	.16	.12	.14
Lack of information about growing crop	2.0	*.09*	.29	.32	.21	.05	.13

Risk involved with growing a new crop	2.0	*.08*	.30	.35	.20	.05	.11
Lack of access to proper equipment	1.9	*.09*	.37	.27	.17	.07	.12
Lack of renter or contract service provider	1.9	*.10*	.37	.23	.15	.07	.17
Lack of financial assistance	1.9	*.09*	.39	.27	.15	.06	.13
Risk of unsuccessful establishment	1.8	*.08*	.37	.32	.14	.03	.14
Cost to establish	1.7	*.08*	.41	.31	.13	.02	.12
A lapse in income until first harvest	1.7	*.09*	.49	.21	.13	.05	.12
Trees							
Access to equipment for harvesting	1.5	*.08*	.57	.21	.09	.03	.10
Long term commitment for the land (20-30 years)	1.4	*.07*	.65	.16	.06	.04	.09
Having tree roots and stumps in tillable land	1.4	*.07*	.68	.15	.05	.03	.08
Long delay till first harvest (3-12 years)	1.4	*.07*	.69	.15	.05	.04	.08

Table 8: Financial Agreement

	Grasses							**Trees**						
			Rank							**Rank**				
	mean	**±**	**1**	**2**	**3**	**4**	**5**	**mean**	**±**	**1**	**2**	**3**	**4**	**5**
A	3.5	*.16*	.20	.15	.11	.06	.50	4.2	*.14*	.09	.07	.09	.05	.71
B	3.2	*.14*	.18	.17	.16	.27	.23	3.7	*.13*	.11	.09	.13	.34	.34
C	3.3	*.12*	.10	.15	.39	.11	.25	3.6	*.12*	.05	.11	.39	.10	.35
D	3.0	*.14*	.15	.31	.13	.17	.24	3.2	*.15*	.12	.34	.10	.14	.30
E	2.8	*.17*	.36	.14	.11	.08	.31	2.8	*.18*	.40	.12	.09	.06	.33

Table 9: Willingness to Supply

	Grasses				**Trees**			
	yes		**acres|yes**		**yes**		**acres|yes**	
	%	**±**	**mean**	**±**	**%**	**±**	**mean**	**±**
-$100	0.17	*.10*	30	*13*				
-$50	0.17	*.10*	36	*23*	0.04	*.05*	13	*5*
$0	0.62	*.12*	75	*23*	0.42	*.14*	35	*18*
$50	0.69	*.13*	69	*22*	0.40	*.13*	31	*12*
$100	0.71	*.11*	80	*25*	0.47	*.13*	46	*17*
$150	0.65	*.13*	77	*24*	0.49	*.13*	48	*14*
$200	0.80	*.10*	82	*27*	0.48	*.13*	65	*28*
$250	0.83	*.10*	85	*31*	0.53	*.13*	59	*21*
$300					0.58	*.13*	74	*26*

Table 10: Farmland to target

	%	±

Poor quality soil	0.44	*.05*
Sloped land	0.38	*.05*
Poorly drained soils	0.38	*.05*
Land near a lake, river or stream	0.33	*.05*
Sandy soils	0.29	*.04*
All my land	0.18	*.04*
Most productive land	0.07	*.02*

Table 11: Models for Willingness to Supply Perennial Grasses

Model	(1) Tobit		(2) Truncated Normal Hurdle				(3) Lognormal Hurdle				(4) Exponential Type II Tobit			
	acres		yes		acres|yes		yes		log(acres)|yes		yes		log(acres)|yes	
net income amount	.16**	0.07	.008***	(.002)	0.014	(0.11)	.008***	(.002)	.0008	(.0008)	.009***	(.003)	.0006	(.0004)
positive net income amount	96.79***	22.30	1.89***	(.477)	219.74***	(78.15)	1.89***	(.477)	.7907**	(.3280)	2.024***	(.619)	.862**	(.3233)
corn/soybean rotation	5.14	14.43	.192	(.388)			.192	(.388)			.454	(.446)		
acres lease TO					.28***	(.08)			.0016***	(.0006)			.0015**	(.0006)
acres owned					0.06	(.06)			.0006**	(.0003)			.0006	(.0004)
length of ownership	-0.16	0.16	.001	(.004)	-0.88***	(.29)	.001	(.004)	-.0026	(.0019)	.003	(.004)	-.0038**	(.0017)
sold agriculture					-4.42	(5.56)			-.0007	(.0327)			.0078	(.0419)
sold non-agriculture					-3.90	(5.38)			-.0106	(.0361)			-.0183	(.0333)
recreation					-42.96***	(13.76)			-.23***	(.0725)			-.23***	(.0692)
different crop					16.01	(10.89)			.1180*	(.0685)			.1151	(.0710)
conservation working lands					-80.04**	(32.40)			-.2661	(.2208)			-.401	(.2590)
conservation easement					50.45**	(23.53)			.2101	(.2007)			.3049*	(.1686)
soil conservation					30.24	(20.53)			.1029	(.1391)			.123	(.1438)
awareness	1.08	5.58	.127	(.159)	-6.77	(14.53)	.127	(.159)	-.0702	(.0907)	.169	(.203)	-.0713	(.0803)
interest	37.30***	9.29	1.33***	(.182)	29.82	(19.39)	1.33***	(.182)	.1666	(.1285)	1.209***	(.298)	.1572	(.1037)
soil quality			-.276**	(.133)			-.276**	(.133)			-.414**	(.175)		
habitat					19.93*	(12.19)			.1092	(.0793)			.1066	(.0831)
diversify reduce risk			.056	(.059)			.056	(059)			.035	(.077)		
land steward			-.45***	(.136)			-.45***	(.136)			-.43***	.169)		
energy independence			.273**	(.129)	-12.61	(10.35)	.273**	(.129)	-.0844	(.0737)	.33**	.159)	-.0460	(.0738)
conserve for future gen.			.286	(.206)			.286	(.206)			.258	.311)		
lack of access to equipment			.489***	(.176)			.489***	(.176)			.57***	(.219)		
risk with new crop					-34.20**	(15.31)			-.214**	(.1072)			-.221**	(.0899)
time to learn new system					15.76	(11.18)			.1163	(.0826)			.1172	(.0775)
lack of financial assistance			-.532***	(.163)			-.532***	(.163)			-.59***	(.213)		
loss of loan eligibility			.325***	(.117)			.325***	(.117)			.41***	(.142)		
financial agreement D	-6.40	4.15	-.315***	(.119)			-.315***	(.119)			-.172	(.135)		

Model	(1) Tobit		(2) Truncated Normal Hurdle				(3) Lognormal Hurdle				(4) Exponential Type II Tobit			
	acres		yes		acres|yes		yes		log(acres)|yes		yes		log(acres)|yes	
sloped land	8.69	11.69	-.397	(.273)			-.397	(.273)			-.262	(.361)		
male			.935**	(.381)			.935**	(.381)			1.20***	(.454)		
age	0.25	0.52	.012	(.012)			.012	(.12)			.008	(.016)		
work off-the-farm			-0.495*	(.305)	21.79	(31.42)	-0.495*	(.305)	.0811	(.1641)	-.497	(.403)	.0502	(.1559)
part-time farmer			1.213***	(.421)			1.213***	(.421)			1.25**	(.530)		
land location					27.41***	(9.86)			.1548***	(.0518)			.165***	(.0656)
debt ratio	3.72	6.00	.136	(.167)	-0.79	(9.86)	.136	(.167)	.0089	(.0728)	.182	(.166)	.006	(.067)
household income	8.68**	4.37	.260***	(.090)	9.16	(8.68)	.260***	(.90)	.0598	(.0557)	.309**	(.127)	.077	(.0527)
farm income	17.55***	5.02			45.80***	(12.86)			.2453***	(.0669)			.237***	(.0581)
constant	-284***	68.41	-8.2***	(1.89)	-498.2***	(140.31)	-8.2***	(1.89)	1.35**	(.6009)	-9.2***	(2.634)	1.24*	(.724)
σ	75.1***	8.02			74.6***	(985)							.667***	(.043)
ρ													-.051	(.363)
N														
Log likelihood	-942.53		-728.98				-197.36				-174.56			

***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

Table 12: Models for Willingness to Supply Short Rotation Woody Crops

Model	(1) Tobit		(2) Truncated Normal Hurdle				(3) Lognormal Hurdle				(4) Exponential Type II Tobit			
	acres		yes		acres|yes		yes		log(acres)|yes		yes		log(acres)|yes	
net income amount	.13***	(.05)	.002	(.001)	.17***	(.06)	.002	(.001)	.0020***	(.0007)	.002	(.001)	.0021***	(.0007)
positive net income amount	100.78***	(22.64)	3.243***	(.583)	74.12*	(43.54)	3.243***	(.583)	.7016	(.7262)	3.319***	(.780)	.7000	(.704)
acres owned					.08***	(.02)			.0012**	(.0005)			.0013***	(.0004)
acres lease TO					-0.07	(.04)			-.0010	(.0007)			-.0011*	(.0006)
acres rent from	0.03***	(.01)	.023**	(.011)			.023**	(.011)			.023	(.021)		
acres farmed			-.021**	(.011)			-0.021**	(.011)			-.021	(.021)		
corn/soybean rotation			.101	(.326)			.101	(.326)			.152	(.349)		
length of ownership			.007*	(.004)			.007*	(.004)			.007*	(.004)		
conservation working lands			.716*	(.427)	-28.87	(18.38)	.716*	(.427)	-.3070	(.2237)	.680	(.530)	-.3347*	(.201)
operated by family members	-8.29***	(3.08)			-8.83	(7.27)			-.1315**	(.0602)			-.1310**	(.054)
sold agriculture	1.72	(2.62)	.071	(.064)			.071	(.064)			.079	(.082)		
sold non-agriculture	1.57	(2.21)	.199***	(.057)			.199***	(.057)			.199***	(.083)		
recreation	2.04	(4.17)	.228*	(.122)	-5.76	(7.56)	.228*	(.122)	-.0102	(.0715)	.212	(.136)	-.0154	(.067)

Model	(1) Tobit		(2) Truncated Normal Hurdle				(3) Lognormal Hurdle				(4) Exponential Type II Tobit			
	acres		yes		acres|yes		yes		log(acres)|yes		yes		log(acres)|yes	
diversify current uses			.263**	(.109)			.263**	(.109)			.261**	(.130)		
habitat	1.64	(5.21)	.303**	(.142)	-4.42	(8.08)	.303**	(.142)	.0620	(.1089)	.324*	(.179)	.0804	(.099)
perennial could provide habitat	1.81	(3.15)			1.10	(5.39)			.0368	(.0633)			.0331	(.058)
land steward					18.18***	(6.06)			.1188*	(.0708)			.1231*	(.065)
awareness			-.262*	(.137)	-18.04**	(7.88)	-.262*	(.137)	-.1546**	(.0769)	-.278*	(.152)	-.151**	(.071)
interest	26.00***	(5.50)	.869***	(.153)	22.59*	(13.10)	.869***	(.153)	.1565*	(.0827)	.853***	(.170)	.155*	(.091)
financial agreement B					5.39	(7.11)			.0695	(.0623)			.0619	(.057)
financial agreement D	-8.49***	(3.05)	-.324***	(.103)			-.324***	(.103)			-.311***	(.109)		
lack of information on new crop					19.43***	(7.60)			.1990**	(.0844)			.210***	(.077)
Lack of renter or contract service			-.308***	(.119)	-18.0***	(5.03)	-.308***	(.119)	-.1679**	(.0722)	-.302**	(.127)	-.165**	(.066)
tree roots in tillable land			.652***	(.150)			.652***	(.150)			.617***	(.183)		
poorly drained soils	-15.58	(9.82)	-1.05***	(.278)			-1.05***	(.278)			-1.02***	(.303)		
poor quality soils	-9.34	(8.85)	-.490*	(.257)			-.490*	(.257)			-.457	(.305)		
sloped land	25.45***	(8.92)	1.148***	(.286)			1.148***	(.286)			1.101***	(.319)		
age	.06	(.48)	-.001	(.013)	1.12*	(.65)	-.001	(.013)	.0019	(.0066)	-.001	(.012)	.0027	(.006)
work off-the-farm	-13.68	(12.29)	-.038	(.311)	-21.14	(18.18)	-.038	(.311)	-.1084	(.1844)	-.048	(.327)	-.1047	(.169)
full-time farmer					-43.68***	(13.82)			-.528***	(.1975)			-.517***	(.183)
part-time farmer	25.93**	(10.45)	1.599***	(.375)			1.599***	.375			1.550***	(.425)		
debt ratio	7.65	(4.77)	.042	(.137)	25.45***	(6.71)	.042	.137	.2210***	(.0645)	.040	(.154)	.234***	(.060)
Household income	8.41**	(3.59)	.00001	(.103)	13.55**	(5.42)	.00001	.103	.1029*	(.0534)	.008	(.103)	.107**	(.052)
farm income			.113	(.097)	24.25***	(5.45)	.113	.097	.3104***	(.0664)	.107	(.107)	.310***	(.063)
constant	-204.55	(58.97)	-7.65***	(1.534)	-388***	(102.37)	-7.65***	1.534	-.4168	(1.006)	-7.78***	(1.64)	-.5657	(1.10)
σ	52.00	(5.00)			40.63	(7.28)							.585	(.041)
ρ													.011	(.372)
N														
Log likelihood	-647.42		-538.90				-164.52				-161.97			

***Significant at the 1% level, **Significant at the 5% level, *Significant at the 10% level

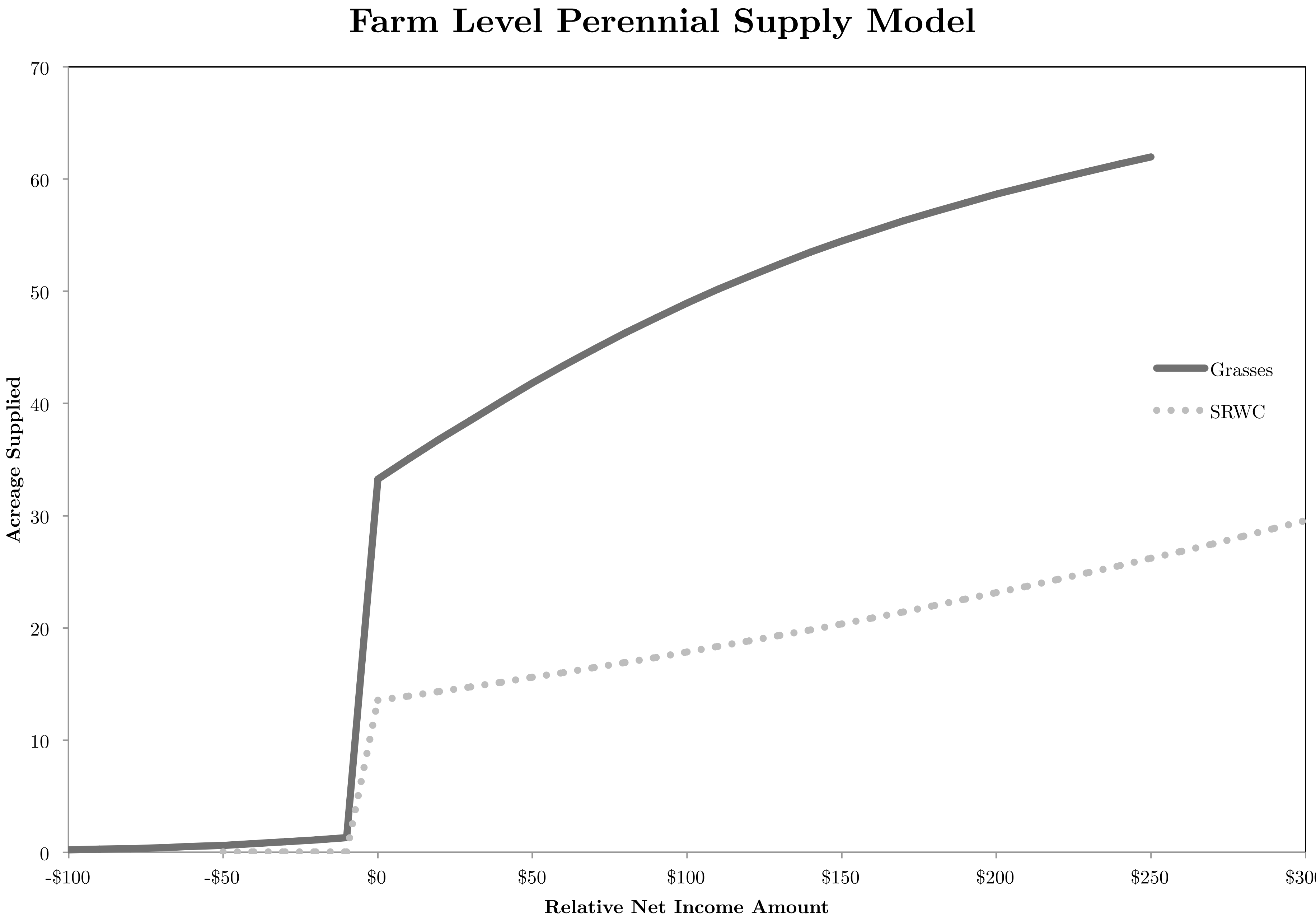

Figure 1: Farm Level Perennial Supply Model

10. References

Altman, I., Sanders, D., & Moon, W. (2010). Producer Willingness and Ability to Supply Biomass. WERA-72 Annual Meeting.

Atwell, R., & La Schulte. (2011). Tweak, Adapt, or Transform: Policy Scenarios in Response to Emerging Bioenergy Markets in the US Corn Belt. Ecology and Society.

Atwell, R., Schulte, L., & Westphal, L. (2009a). Landscape, community, countryside: linking biophysical and social scales in US Corn Belt agricultural landscapes. Landscape Ecology, 24(6), 791-806.

Atwell, R., Schulte, L., & Westphal, L. (2009b). Linking resilience theory and diffusion of innovations theory to understand the potential for perennials in the US Corn Belt. Ecology and Society, 14(1), 30.

Atwell, R., Schulte, L., & Westphal, L. (2010). How to build multifunctional agricultural landscapes in the US Corn Belt: Add perennials and partnerships. Land Use Policy, 27(4), 1082-1090.

Bocquého, G. (2010). The adoption of switchgrass and miscanthus by farmers: Impact of liquidity constraints and risk preferences. Energy Policy, 38, 2598-2607.

Dillman, D., & Smyth, J. (2008). Internet, mail, and mixed-mode surveys: The tailored design method (Third Edition.). Hoboken, New Jersey: John Wiley & Sons Inc.

Jensen, K., Clark, C., Ellis, P., English, B., & Menard, J. (2007). Farmer willingness to grow switchgrass for energy production. Biomass and Bioenergy, 31, 773-781.

Jolejole, C. B., Swinton, S. M., & Lupi, F. (2009). Incentives to Supply Enhanced Ecosystem Services from Cropland. In 2009 AAEA & ACCI Joint Annual Meeting. Presented at the 2009 AAEA & ACCI Joint Annual Meeting, Milwaukwee, WI.

Larson, J. A., English, B. C., & Lambert, L. (2007). Economic Analysis of the Conditions for Which Farmers Will Supply Biomass Feedstocks for Energy Production..” Ames, Iowa: Agricultural Marketing Resource Center.

Larson, J., English, B., & He, L. (2008). Risk and Return for Bioenergy Crops under Alternative Contracting Arrangements. In 2008 Southern Agricultural Economics Association Annual Meetings. Presented at the 2008 Southern Agricultural Economics Association Annual Meetings, Dallas, TX.

Larson, J., English, B., & Hellwinckel, C. (2005). A Farm-Level Evaluation of Conditions Under Which Farmers Will Supply Biomass Feedstocks for Energy Production. In 2005 American Agricultural Economics Association Annual Meeting. Presented at the 2005

American Agricultural Economics Association Annual Meeting, Providence, RI.

Paulrud, S., & Laitila, T. (2010). Farmers' attitudes about growing energy crops: A choice experiment approach. Biomass and Bioenergy, xxx, 1-10.

Scheffran, J., & BenDor, T. (2009). Bioenergy and land use: a spatial-agent dynamic model of energy crop production in Illinois. International Journal of Environment and Pollution, 39(1/2), 4-27.

Welsh, R., Carpentier, C., & Hubbell, B. (2001). On the Effectiveness of state anti-corporate farming laws in the United States. Food Policy, 26, 543-548.

Willock, J., Deary, I. J., Edwards-Jones, G., Gibson, G. J., McGregor, M. J., Sutherland, A., Dent, J. B., et al. (1999). The role of attitudes and objectives in farmer decision making: business and environmentally-oriented behaviour in Scotland. ... Journal of Agricultural Economics, 50, 286-303.

Wooldridge, J. M. (2002). Econometric analysis of cross section and panel data (Second Edition.). Cambridge, Massachusetts: The MIT Press.