Subjective Risks and Barriers to Perennial Bioenergy Production: Estimating a Structural Model with Data from a Hypothetical Market Experiment

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Abstract

Due in part to concerns over energy security and the environmental impacts of fossil fuels, recent United States energy policy has included provisions to promote renewable energy. The Energy Policy Act includes provisions for advanced biofuels from cellulosic biomass. Perennial bioenergy crops such as perennial grasses and woody crops are an alternative source of feedstock for biofuel with lower environmental impacts than their annual counterparts.

Previous work has shown that, when perennial grasses are financially competitive with a farmer's current crops, a majority of farmers will produce perennial grasses but only on a small portion of their land. One potential explanation for this is the risk posed by growing a new crop and selling it into a new emerging market.

Therefore this study uses the land allocation under risk framework developed by Just and Zilberman (1988) to estimate structural parameters. The structural system is estimated using full information maximum likelihood. Observation of the acreage choice is conditional on the risk-adjusted profits being positive making the estimation method analogous to Heckman's simultaneous sample correction method. As a result of using a structural mixed-processes system the scale parameter of the discrete choice equation can be identified.

Results suggest that agricultural landowners perceive an order of magnitude higher risk to perennial bioenergy production than their current production system. These results are partly driven by the risk management options currently available for commodity crops such as crop insurance, futures markets, and risk reducing inputs. Agricultural landowners also perceive woody crops as risker and with higher adoption costs than perennial grasses.

Introduction

Due in part to concerns over energy security and the environmental impacts of fossil fuels, recent United States energy policy has included provisions to promote renewable energy. In the transportation sector, which relies almost exclusively on liquid fuels, renewable energy is based primarily on corn ethanol and soy biodiesel. Therefore, policies encouraging renewable energy have help drive demand for agricultural commodities. This has resulted in a land-use shift from perennial conservation acres, pasture, and hay to annual field crops such as corn and soybean (Motamed, McPhail, and Williams 2016; U. S. Department of Agriculture 2013). This change in land use has several environmental consequences including increases in greenhouse gas emissions and reductions in water quality (Fargione et al. 2008; Rajagopal et al. 2007).

The Energy Policy Act (2005, 2007) does include provisions for advanced biofuels from cellulosic biomass (i.e., structural material of plants). However, commercial scale production, which utilizes annual crop residues for its primary feedstock, has been lagging far below the required production mandates. Cellulosic biofuels from crop residues further increase the environmental impacts of US liquid fuels energy policy by reducing surface residue which can increase erosion(Lal 2005).

Perennial bioenergy crops such as perennial grasses and woody crops are an alternative source of feedstock for biofuel with lower environmental impacts than their annual counterparts (Lemus and Lal 2005; McLaughlin and Walsh 1998). Perennial bioenergy crops can mitigate the environmental impacts of changing land use that has resulted from the Energy Policy Act and increase the sustainability of U.S. energy policy.

The 2008 Farm Bill included provisions to support biomass production on agricultural land. The Biomass Crop Assistance Program (BCAP) provides payments for perennial production establishment, payments based on acreage, and price matching payments. Eligible crop producers can receive reimbursements for up to 75 percent of their establishment costs, up to five years of annual payments and price matching up to $45 per dry ton.

Previous work (Smith 2015) has shown that, when perennial grasses are financially competitive with a farmer's current crops, a majority of farmers will produce perennial grasses. However, they are only willing to plant perennials on a small portion of their land. One potential explanation for this is the risk posed by growing a new crop and selling it into a new emerging market (Just and Zilberman 1988). The relative magnitude of the risk can affect both the willingness to produce and the number of acres. Crops that are financially competitive, but pose greater risks than their current crops, will be tested in a small area as part of a diversified production portfolio. This strategy will reduce aggregate risk (Bocquého and Jacquet 2010; Larson, English, and He 2007).

New cropping regimes require a significant investment in both human capital and capital goods. When the agronomics differ as widely as they do between conventional and perennial bioenergy crops, large investments in the development of human capital resources must be undertaken to successfully and optimally manage the new system.

Understanding the magnitude of the risks and the fixed adoption costs can help to better predict perennial supply and the impact of government policies. Farmers' preferences can limit the effectiveness of subsidies in cases where subsidies are risk increasing.

This study estimates the relative risk ratio and fixed adoption costs for perennial grasses and woody crops by parameterizing a structural model of crop choice under risk. Previous work has estimated perennial acreage using simulations of a crop-choice under risk framework (Bocquého and Jacquet 2010; Larson, English, and He 2007). We use a similar structural model of crop choice under risk, but estimate the parameters econometrically using data from a hypothetical market experiment of agricultural landowners from the Upper Mississippi River Basin.

We choose to develop and estimate a structural model, which has several advantages. First, it provides a theoretical explanation for the the choice of explanatory variables, including their interactions. Second, it provides for a behavioral interpretation of the coefficients of these variables and their marginal effects as it relates to crop choice under risk. Third, parameters of the crop choice model, including the relative risk ratio and the fixed adoption costs can be estimated, which is not possible with the reduced form approach. Fourth, using the structural relationship between the discrete and continuous variables, we can estimate the variance of the error of the risk-adjusted profit. Fifth, using the simultaneous Heckman correction and the nonlinear constraints, we can reduce the bias of the results due to sample selection while increasing the efficiency of the estimator over multi-step procedures.

Conceptual Model

While approaches to choice under uncertainty, such as the state-contingent model, have many conceptual advantages, many lack the mathematical traceability of expected utility. In addition, the expected utility model still allows us to explore risk, a specific construct of uncertainty. The expected utility model gives us an explicit solution for the risk adjusted profit and the optimal acreage. Finally, we can use the optimal conditions to establish the comparative static effects of the policy levers, relative returns, and available acreage ($\bar{L}$). Assuming the per acre returns are random and distributed normally $\tilde{\pi} \sim N(\pi, \sigma)$, and that the landowners have constant absolute risk aversion (CARA) ($U(\tilde{\pi}) = 1 - e^{-\phi\tilde{\pi}}$ where $\phi = -U''(\bar{w})/U'(\bar{w})$), we can transform the utility function into the certainty equivalent model $E(U) = \pi - \frac{\phi}{2}\sigma^2$ using Freund (1956), where σ^2 is the variance of the profit.[1]

The profit function is defined using per acre net profits (π) for a farmer's current production system ($_c$) and a perennial bioenergy crop ($_p$). Total profits are perennial profits from production on perennial acreage (L_p) plus current profits on available land ($\bar{L}$), minus the opportunity cost of perennial acreage. The profit function includes three policy levers: price subsidy (γ), per acre subsidy (τ), and establishment subsidy (κ). We define the profit

[1]The non-monetary per acre net benefits are the non-pecuniary benefits per acre minus the non-pecuniary cost plus a misspecification parameter.

function as

$$(1) \quad \tilde{\pi} = L^p\left(\gamma\tilde{\pi}_p + \tau\right) + \left(\bar{L} - L^p\right)\left(\tilde{\pi}_c\right) - K + \kappa$$

where per acre profits are random. Our certainty equivalent objective function is then,

$$(2) \quad \begin{aligned} \max_{\substack{L_p \geq 0 \\ A=0,1}} \; V = \pi_c\bar{L} - \frac{\phi}{2}\bar{L}^2\sigma_c^2 + A\Big[&(\pi_p - \pi_c)L_p + (b+\tau)L_p - K + \kappa \\ &- \frac{\phi}{2}\left(L_p^2\gamma^2\sigma_p^2 + (L_p^2 - 2\bar{L}L_p)\sigma_c^2 + 2L_p\left(\bar{L} - L_p\right)\rho\gamma\sigma_p\sigma_c\right)\Big], \quad \text{s.t.} \quad L_p \leq \bar{L}. \end{aligned}$$

We do not assume an interior solution and so A is the decision to produce perennials or not. Following Just and Zilberman (1988), the solution to the maximization problem is,

$$(3) \quad L_p^* = \begin{cases} \bar{L} & \text{if} \quad A = 1 \quad \text{and} \quad V'(\bar{L}) \geq 0 \\ \tilde{L}_p & \text{if} \quad A = 1 \quad \text{and} \quad V'(\tilde{L}_p) = 0 \\ 0 & \text{if} \quad A = 0 \end{cases}$$

where $\tilde{L}_p = [\pi^p - \pi^c + b + \tau]\,\phi^{-1}(\sigma_p^2\gamma^2 + \sigma_c^2 - 2\rho\sigma_p\gamma\sigma_c)^{-1} + \bar{L}(\sigma_c^2 - \rho\sigma_p\gamma\sigma_c)(\sigma_p^2\gamma^2 + \sigma_c^2 - 2\rho\sigma_p\gamma\sigma_c)^{-1}$ is the optimal perennial acreage with an interior solution and L_p^* is the optimal perennial acreage. Farmers will grow perennial bioenergy crops ($A = 1$) when the risk adjusted profit is positive,

$$(4) \quad \begin{aligned} &(\pi_p\gamma - \pi_c)L_p + (b+\tau)L_p - K + \kappa \\ &- \frac{\phi}{2}\left(L_p^2\gamma^2\sigma_p^2 + (L_p^2 - 2\bar{L}L_p)\sigma_c^2 + 2L_p\left(\bar{L} - L_p\right)\rho\gamma\sigma_p\sigma_c\right) > 0. \end{aligned}$$

By assuming an interior solution, equation (4) can be written as $\tilde{L}_p^2\frac{\phi}{2}\,\mathrm{Var}(\pi_p - \pi_c) > K - \kappa$, where $\mathrm{Var}(\pi_p - \pi_c) = \gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c$. The left hand side is always non-negative. Assuming the fixed costs of perennials minus the establishment subsidy is positive $K - \kappa > 0$ then the farmer will not grow perennials ($A = 0$) when $\tilde{L}_p < \sqrt{2\frac{K-\kappa}{\phi\,\mathrm{Var}(\pi_p - \pi_c)}}$. Given the optimal interior solution the farmer must produce enough perennial acreage so that the risk adjusted profits are greater than the fixed costs of perennials.

Comparative Statics

In this section we determine the comparative static effects of the policy levers, relative returns and the available acreage.

Establishment Subsidy: Given that we have assumed CARA, an establishment subsidy does not effect the optimal perennial acreage (Smith 2015). This is not a surprising result since we know that, with CARA, the risk aversion remains constant as the level of profit changes.

Annual Subsidy, Non-pecuniary Benefits, Relative per acre returns: A per acre subsidy has a positive impact on acreage when the landowner has CARA preferences (Smith 2015). There is no scale effect with CARA preferences but there is a substitution from conventional to perennial bioenergy crops with a per acre subsidy. Using the certainty equivalent approach, we can determine not only the direction of the effect but also the magnitude. Assuming an interior solution the per acre subsidy effect on perennial acreage is

$$\frac{\partial \tilde{L}_p}{\partial \tau} = \frac{1}{\phi(\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)}. \tag{5}$$

This value is always positive given that the individual is risk averse ($\phi > 0$) and $\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c = \mathrm{Var}(\pi^p - \pi^c) > 0$. The comparative static effect is equal to the effect of the non-monetary benefits and the relative per acre returns on perennial acres, $\frac{\partial \tilde{L}_p}{\partial \tau} = \frac{\partial \tilde{L}_p}{\partial b} = \frac{\partial \tilde{L}_p}{\partial(\pi_p - \pi_c)}$.

Land: The relationship between total acreage and perennial acreage is,

$$\frac{\partial \tilde{L}_p}{\partial \bar{L}} = \frac{\sigma_c^2 - \rho\sigma_c\gamma\sigma_p}{\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c}. \tag{6}$$

This value is positive when $\sigma_c > \rho\gamma\sigma_p$ and negative otherwise. Using $\rho = \frac{\sigma_{cp}}{\sigma_c\gamma\sigma_p}$, the comparative static effect of available land on perennial acreage is positive when the variance of conventional returns is greater than the covariance of the conventional and perennial returns ($\sigma_c^2 > \sigma_{cp}$).

Relative Risks

Using equation 6 we can determine the relationship between the conventional and perennial return risks:

$$(7) \qquad \left(\frac{\partial \tilde{L}_p}{\partial \bar{L}}\right)^{-1} - 1 = \frac{\gamma^2\sigma_p^2 - \rho\gamma\sigma_p\sigma_c}{\sigma_c^2 - \rho\sigma_c\gamma\sigma_p}.$$

This is the perennial per acre return variance minus the conventional and perennial per acre return covariance. If the correlation (ρ) is equal to zero, then this is the ratio of the per acre return variances. If the correlation is equal to one, then this is the negative of the ratio of the standard deviations. If the correlation is equal to minus one, then this is the ratio of the standard deviations.

If this ratio is greater than one, the perennial per acre profit risks are greater than the current per acre profit risks ($\gamma^2\sigma_p^2 > \sigma_c^2$). If this ratio is less than one then the current per acre profits risk are greater ($\gamma^2\sigma_p^2 < \sigma_c^2$). If it is equal to one then the per acre profit risks are equal ($\gamma^2\sigma_p^2 = \sigma_c^2$). Note that this result doesn't require any assumptions about the correlation between current and perennial per acre returns.

Using this relationship and equation 7 we can show that when the comparative static effect of land on perennial acres is less than one-half, the perennial per acre profits risk is greater than the current per acre profit risk ($\gamma^2\sigma_p^2 > \sigma_c^2 \Leftrightarrow \frac{\partial \tilde{L}_p}{\partial \bar{L}} > \frac{1}{2}$). The intuition behind this results from recognizing that the land comparative static effect is equal to the fraction of land planted to perennials when evaluated at zero relative profit ($\frac{\partial \tilde{L}_p}{\partial \bar{L}} = \frac{\tilde{L}_p(\pi_p - \pi_c + b + \tau = 0)}{\partial \bar{L}}$). The landowner is deciding how to allocate his/her land between two risky crops. If risk and returns are the same for both crops then producing equal areas minimizes the aggregate risk. If the returns are the same for two crops and the risks are greater for one crop the landowner will allocate less land to the risker crop.

Empirical Methods

Our conceptual model above outlined the certainty equivalent utility function equation (2) for crop choice under risk. When solved for the optimal perennial acreage, the certainty equivalent utility function gives us a set of analytical solutions and comparative static effects. The observable variables were collected using a survey, which included stated choice questions with randomized perennial crops returns relative to conventional crop returns. Here we use the same data but specify the structural relationship as outlined in the conceptual model.

The farmer's decision is two-fold: whether or not to produce perennial crops and how much acreage to allocate for perennial production. Based on the conceptual model the decision to produce or not depends on how many acres would be planted if in fact, perennials are planted. This is because the acreage decision affects the expected profit and the risk. However, the acreage decision is only observed for the farmers who choose to produce. First, we outline the econometrics needed to estimate the two decisions independently. Once we have a clear understanding of these two decisions, we can outline techniques to deal with the inter-dependency and the unobserved data.

Willingness to Supply

The willingness to supply (WTS) questions in the survey were designed as closed-ended pure dichotomous choice questions. This minimizes bias by avoiding leading the respondent. 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:

(8) $$U(\tilde{\pi}_p - \tilde{\pi}_c, L_p, \bar{L}, K, b)$$

where the variables are defined as they are in equation (2). The WTS questions ask respondents if they would grow perennial crops given a randomized net return relative to their current crop choices. The respondent will answer "yes" to the question if

(9) $$U(A = 1) > U(A = 0),$$

where the left hand side of the inequality (9) is the utility from producing perennials and the right hand side is the utility from producing no perennials. Using the certainty equivalent utility, equation (2) and equation (9), we have the conditions under which adoption occurs,

(10)
$$V = V^1 - V^0$$
$$= (\pi_p - \pi_c + \tau)L_p + bL_p - K - \frac{\phi}{2}\left(L_p^2\gamma^2\sigma_p^2 + (L_p^2 - 2\bar{L}L_p)\sigma_c^2 + 2L_p(\bar{L} - L_p)\rho\gamma\sigma_p\sigma_c\right) > 0,$$

which is the certainty equivalent of the utility of adoption ($V^1(A=1)$) minus the certainty equivalent of utility of not adopting ($V^0(A=0)$). The utility is unobservable but the dichotomous choice, relative returns per acre, and the available land is observable. The adoption decision, as outlined in equation (2), is dependent on the optimal interior perennial acreage. The perennial acreage is only observable for respondents answering "yes" to the WTS question. Based on our conceptual model, the respondents answering "no" to the WTS question must have had a perennial acreage in mind when they made the decision to produce or not. This is because the perennial acreage effects the risk adjusted profit. An estimate of the perennial acreage can be determined from the observable assuming the optimal perennial acreage solution. Therefore we substitute the optimal perennial acreage given adoption into equation (10). The probability model is then,

$$\text{(11)} \quad \Pr\left[\frac{(\pi_p - \pi_c + b + \tau)^2}{2\phi(\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)} + \frac{(\pi_p - \pi_c + b + \tau)(\sigma_c^2 - \rho\sigma_c\gamma\sigma_p)}{(\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)}\bar{L} + \frac{\phi(\sigma_c^2 - \rho\sigma_c\gamma\sigma_p)^2}{2(\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)}\bar{L}^2 - K > \varepsilon_A\right]$$

where $\varepsilon_A = \varepsilon_1 - \varepsilon_0$ is the error in the estimates of the risk adjusted profit which is something that we don't observe. In order to simplify this equation we define $\beta_1 = \phi^{-1}(\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)^{-1}$ and $\beta_2 = (\sigma_c^2 - \rho\sigma_c\gamma\sigma_p)(\gamma^2\sigma_p^2 + \sigma_c^2 - 2\rho\gamma\sigma_p\sigma_c)^{-1}$. Substituting this into the previous equation we have

$$\text{(12)} \quad \Pr\left[\frac{\beta_1}{2}(\pi_p - \pi_c + b)^2 + \beta_2(\pi_p - \pi_c + b)\bar{L} + \frac{\beta_2^2}{2\beta_1}\bar{L}^2 - K > \varepsilon_A\right].$$

Using this probability model and reducing the unobservables to a single coefficient on the observables and noting that the probability model is normalized to the standard normal for a probit estimation, we can determine the estimation equation,

$$\Phi\left(\alpha_1(\pi_p - \pi_c) + \alpha_2\bar{L} + \alpha_3\bar{L}(\pi_p - \pi_c) + \alpha_4(\pi_p - \pi_c)^2 + \alpha_5\bar{L}^2 + \alpha_6\right) \quad (13)$$

where $\alpha_1 = b\beta_1/\sigma$, $\alpha_2 = b\beta_2/\sigma$, $\alpha_3 = \beta_2/\sigma$, $\alpha_4 = \beta_1/(2\sigma)$, $\alpha_5 = \beta_2^2/(2\beta_1\sigma)$, and $\alpha_6 = -K\sigma^{-1} + b^2\beta_1/(2\sigma)$. This is the reduced form equation were the independent variables are the relative net return, available land, squares and interactions. The normalization parameter prevents an estimation of the β parameters.

Perennial Acreage

If the respondents answer yes to the willingness to supply question, they are asked a follow up question on the acreage they would use for perennial crop production given the relative expected net incomes per acre. The linear estimation model of the perennial acreage using the certainty equivalent model is,

$$L_p = \beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \varepsilon_L \quad (14)$$

where $\beta_3 = b/\beta_1$. This equation which can be estimated by ordinary least squares (OLS) regression for the observations in which the acreage is positive, assuming that $\varepsilon_L \sim N(0, \sigma_{\varepsilon_L})$. Equation (14) directly estimates the β parameters and the estimate of b can be obtain by β_3/β_1. This linear equation is only a consistent estimator of the coefficients if

$$\mathbb{E}\left[\beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \varepsilon_L \middle| A = 1\right] = \mathbb{E}\left[\beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \varepsilon_L\right]. \quad (15)$$

The acreage decision is observed if $A = 1$, thus the subsample will include only observations for which $L_p \geq \sqrt{2K\beta_1}$. Those farmers that perceive a high risk of perennials would allocate a lower fraction of land making it less likely that they would adopt. Substituting for L_p, this becomes $\varepsilon_L \geq \sqrt{2K\beta_1} - \mathbb{E}[L_p]$, which shows that μ is bound from below. Given that ε_L is normally distributed, $\mathbb{E}[\varepsilon_L|A=1] > \mathbb{E}[\varepsilon_L] = 0$ therefore

$$\mathbb{E}\left[\beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \varepsilon_L|A=1\right] = \beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \mathbb{E}[\varepsilon_L|A=1]. \tag{16}$$

where $\mathbb{E}[\varepsilon_L|A=1]$ is the source of the sample selection bias.

Self Selected Sample

The coefficients of the acreage decision can be consistently estimated by the selected sample, of respondents that indicated perennial crop adoption, if the expectations of the selected sample equal that of the random sample. If this is not the case, as we have shown, the estimates are biased. The Heckman correction model is commonly used to account for this bias (Heckman 1979). The perennial acreage is only observed if $L_p \geq \sqrt{2K\beta_1}$. The simultaneous Heckman correction is a system of equations

$$1\{V > 0\} = V(\alpha) + \varepsilon_A \tag{17a}$$

$$L_p = \beta_1(\pi_p - \pi_c) + \beta_2\bar{L} + \beta_3 + \varepsilon_L. \tag{17b}$$

where $= V(\alpha)$ is the reduced form of equation 13. We assume a bivariate normal $\varepsilon = (\varepsilon_A, \varepsilon_L) \sim N(0, \Sigma)$ with the following variance co-variance matrix

$$\Sigma = \begin{bmatrix} 1 & \sigma_{A,L} \\ \sigma_{A,L} & \sigma_L \end{bmatrix} \tag{18}$$

where $\sigma_{A,L}$ is the covariance of ε_A and ε_L. Using $\rho_{A,L} = \frac{\sigma_{A,L}}{\sigma_A \sigma_L}$ the log likelihood function[2] is,

$$\begin{aligned} &\ln\Phi\left[V(\alpha)\right]^{[L_p \in \emptyset]} + \left[\ln\Phi\left(\frac{V(\alpha) + \rho_{A,L}\frac{L_p - \beta_1(\pi_p - \pi_c) - \beta_2\bar{L} - \beta_1 b}{\sigma_L}}{\sqrt{1 - \rho_{A,L}^2}}\right)\right. \\ &\left. + \ln\phi\left(\frac{L_p - \beta_1(\pi_p - \pi_c) - \beta_2\bar{L} - \beta_1 b}{\sigma_L}\right) - \sigma_L\right]^{L_p \notin \emptyset} \end{aligned} \tag{19}$$

[2] In practice we estimate $\tanh^{-1}\rho_{A,L}$ to restrict $\rho_{A,L}$ to be between minus one and one and $\ln\sigma_L$ to restrict σ_L to positive values

where Φ (ϕ) is the standard normal cumulative distribution (probability density) function (Wooldridge 2002).

Joint Estimation Model

Using the Heckman approach we can get consistent and unbiased estimates of β_1, β_2, and b. Using these estimates and our linear equation we could predict L_p and then estimate the discrete choice equations (i.e. two-step approach) giving us predictions of risk adjusted profit variance σ and the fixed costs (K). Jointly estimating this structural model in a single step will increase the efficiency of the estimator. The system of equations that we are estimating is

(20a)
$$\Pr[A=1] = \Phi\left(\frac{\beta_2 b(\pi_p-\pi_c)+\beta_2 b\bar{L}+\beta_2\bar{L}(\pi_p-\pi_c)}{\sigma_A} + \frac{\beta_1/2(\pi_p-\pi_c)^2+\beta_2^2/(2\beta_1)\bar{L}^2+b^2\beta_1/2+K}{\sigma_A}\right)$$

(20b)
$$L_p = \beta_1(\pi_p-\pi_c)+\beta_2\bar{L}+\beta_1 b.$$

The log likelihood function is

(21)
$$\ln\Phi[-V(\beta)]^{[A=0]} + \ln\Phi[V(\beta)]^{[A=1,L_p\in\emptyset]} + \left[\ln\Phi\left(\frac{V(\beta)+\rho_{A,L}\frac{L_p-\beta_1(\pi_p-\pi_c)-\beta_2\bar{L}-\beta_1 b}{\sigma_L}}{\sqrt{1-\rho_{A,L}^2}}\right) + \ln\phi\left(\frac{L_p-\beta_1(\pi_p-\pi_c)-\beta_2\bar{L}-\beta_1 b}{\sigma_L}\right) - \sigma_L\right]^{[A=1],L_p\notin\emptyset}$$

where $\ln\Phi[V(\beta)]^{[A=1,L_p\in\emptyset]}$ is an additional modification to the log-likelihood function to include observations for which the respondent indicated that they would produce perennials but did not indicate the number of acres for perennial production.

Data

The survey targeted agricultural landowners in nine counties 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. First, these counties have a majority of their land in the lower Minnesota River watershed. Second, they are adjacent to the Koda Energy bioheat and biopower plant and a potential biomass plant site in Madelia, MN. Most of the agricultural land in this region is used to grow corn and soybeans.

Addresses for the agricultural landowners were obtained through each county tax assessors office. Records for parcels zoned for agriculture, with greater than 20 acres, were included in the final study population. This prevents land zoned for agriculture but used for other purposes, such as a homestead, from being included. Duplicate addresses were deleted. The final study population is 13,850 agricultural landowners in the nine counties.

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 at the 95% confidence level.[3] With a population of 13,850 (N_p) and an unknown proportion (p) choosing a response category, we use the proportion (50%) with the most conservative estimate of the sample size. The final sample size needed to be at least 374 agricultural landowners[4] (Dillman, Smyth, and Christian 2008). Given that survey response rates can vary widely and depend on the successful design of the survey, 1000 surveys were mailed anticipating at least a forty percent response rate to achieve the maximum sample size.

Mail Survey Administration

The survey used the standard five-contact Dillman mail survey method (Dillman, Smyth, and Christian 2008). The survey was conducted in late 2010 and early 2011. First, a prenotice letter was mailed to the respondents, approximately one week before the mailing of the first questionnaire, to prepare them to receive the survey. Then, the survey was mailed

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[3] This is a margin of error (B) of 5% and a Z-score (C) of 1.96.

[4] The minimum final sample size is $N_s = \frac{(N_p)p(1-p)}{(N_p-1)(B/C)^2+p(1-p)}$.

Table 1. Summary Statistics

Variable	Description	Mean	St. Dev.	N
Land	Land owned plus land rented	318	393	435
Grass returns	Perennial grass returns per acre relative to current returns per acre	76.9	112	435
Woody crop returns	Woody crop returns per acre relative to current returns per acre	129	113	435
Grass yes	Willing to grow perennial grasses at relative net returns (0,1)	0.59		433
woody crop yes	Willing to grow woody crops at relative net returns (0,1)	0.44		432
Grass acres	Number of acres the landowner is willing to grow perennial grasses on.	80.2	99.2	228
Woody crop acres	Number of acres the landowner is willing to grow woody crops on.	49.1	53.1	170

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 zero to two per day, approximately four weeks after the first survey, a second replacement survey was sent. This survey was mailed in an envelope with a different size and color from that of the first survey and only to addresses that had not yet responded. The final contact involved a reminder postcard about one week after the last survey was mailed.

Table 1 summarizes the data used for the analysis. On average, landowners owned or rented 318 acres. About one-quarter (24 percent) rented land. The crop choice approach randomly assigned per acre net returns for grasses and woody crops relative to their current per acre net returns. The treatments ranged from -$100 to $250 for grass and -$50 to $300 for woody crops at $50 increments. The average grass and woody crop relative returns for surveys received was not significantly different from what we would expect based on a balanced sample ($75 and $125).

Results

Reduced Form Models

Table 2 compares the reduced form models based on equation (19). Model one restricts the error correlation (ρ) to zero (i.e., no simultaneous Heckman correction) and model two includes the error correlation. We estimate these two models for both grasses and woody crops.

For both grasses and woody crops, the relative per acre returns and its square are significant predictors of perennial bioenergy crop adoption. Adoption is increasing in per acre relative perennial returns. The rate of increase is declining with higher relative net incomes. For both grasses and woody crops, adoption is no longer increasing above $400 per acre. The effect of relative net incomes is not significantly different from zero for relative net incomes above approximately $270.

The marginal effect of the relative net income amount, for the acres equation, is 0.19 and 0.12 for grasses and woody crops respectively. Since this is constant, the change in acreage is 19 and 12 acres for each $100 change in relative net income for grasses and woody crops respectively. A farmer with an additional 100 acres of available land will produce 7.8 (0.96) more acres of grasses (woody crops). Using this estimate and the constant coefficient, we can estimate the fraction of land at zero relative net income for the mean available acres. The fraction of available land for producing grasses (woody crops) is 18% (9%).

The second model uses the simultaneous Heckman procedure to correct the bias of the estimation of the acreage equation. The correlation of the errors is not significantly different from zero for either grasses or woody crops.

Structural Model

Tables 3 and 4 illustrate the parameter estimates from the structural model (see equation (21)). Model 3 assumes the ρ and b are equal to zero and Model 4 assumes that ρ is equal to zero. Model 5 is the unrestricted model. We estimate the beta parameters,

Table 2. Reduced Form Coefficients With and Without Heckman Sample selection Correction

	Grasses		Woody crops	
	(1)	(2)	(1)	(2)
Yes				
Land†	0.078*	0.082*	−0.067	−0.070
	(0.040)	(0.042)	(0.049)	(0.052)
Returns†	0.80***	0.80***	0.68***	0.68**
	(0.13)	(0.13)	(0.15)	(0.15)
Land*Returns†	0.0078	0.0090	0.023	0.023
	(0.018)	(0.018)	(0.021)	(0.021)
Land^{2}†	−0.0029	−0.0031	0.0034	0.0036
	(0.0018)	(0.0019)	(0.0032)	(0.0034)
Returns^{2}†	−0.20***	−0.20***	−0.167**	−0.167**
	(0.060)	(0.060)	(0.054)	(0.054)
Constant	−0.20	−0.21*	−0.53***	−0.52***
	(0.12)	(0.13)	(0.15)	(0.15)
Acres				
Returns	0.19*	0.18*	0.116**	0.118**
	(0.080)	(0.082)	(0.040)	(0.040)
Land	0.078*	0.077*	0.0096	0.0098
	(0.030)	(0.030)	(0.0069)	(0.0069)
Constant	31.0*	33.5*	27.0***	25.7***
	(13.3)	(14.1)	(4.9)	(5.6)
σ	63 ***	63 ***	36.2***	36.2***
	(13)	(13.0)	(4.5)	(4.5)
ρ		−0.045		0.030
		(0.041)		(0.033)
log likelihood	−2559.708	−2559.630	−1818.300	−1818.258
N	430	430	430	430

Robust standard errors and are in parentheses; * $p < 0.10$, ** $p < 0.01$, *** $p < 0.001$

† The land and return variables were rescaled for the discrete choice equation to more easily report the results. To obtain the unscaled coefficients and standard errors for land and returns divide by 100. To obtain the unscaled coefficients and standard errors for the interaction and the squared terms divide by 10,000. The returns and land where not rescaled for the acres equation.

the non-pecuniary benefits, fixed capital costs, and the variance of the risk adjusted profit. Using $1/\beta_2 - 1 = (\sigma_p^2 - \sigma_{cp})(\sigma_c^2 - \sigma_{cp})^{-1}$, we estimate the ratio of the variance in the perennial returns minus the covariance over the variance of current returns minus the covariance. Assuming the correlation is zero, this ratio is the ratio of the variances, σ_p^2/σ_c^2. For grasses, the ratio is 36 and significantly different from one (equal variance) at the 90% significance level. For woody crops, the value is 99 but not significantly different from one. These results are partly driven by the relatively low risk of corn and soybean production due to crop insurance, future markets, and risk management strategies. In contrast perennial bioenergy crops lack well established markets, rely on government programs, and do not have the same risk reduction options as corn and soybean. Therefore, landowners' subjective risk of perennial bioenergy production would be much higher than risks for their current crops.

In addition to the parameters that can be estimated from the reduced form models, we can estimate three additional parameters with the structural model. Our estimation of the parameters for the structural models are in table 3 and 4. The structural model allows for an estimation of the fixed capital cost of adoption, which is \$11,000 for grasses and \$14,000 for woody crops. We also estimate the standard deviation of the error of the risk adjusted profit, which is \$18,000 for grasses and \$16,000 for woody crops. For both grasses and woody crops these non-pecuniary benefits are significantly different from zero for the structural model.

Conclusion

This research uses a structural model and stated crop choice approach to examine perennial bioenergy production. Since markets do not currently exist, we randomly assign relative returns to agricultural landowners. Using their stated preferences and a structural model we estimate three determinants of crop choice (risk, non-pecuniary benefits, and capital investment costs).

Table 3. Structural Parameter Estimates for Perennial Grasses with and without Heckman Sample Selection Correction

	Model		
Heckman Correction	No	No	Yes
Parameter	(3)	(4)	(5)
$\frac{1}{\phi(\sigma_p^2+\sigma_c^2-2\rho\sigma_p\sigma_c)}$	0.39***	0.22**	0.19**
	(0.053)	(0.077)	(0.073)
$\frac{\sigma_c^2-\rho\sigma_c\sigma_p}{\sigma_p^2+\sigma_c^2-2\rho\sigma_p\sigma_c}$	0.076***	0.034*	0.027*
	(0.018)	(0.019)	(0.016)
b		199.5*	268.9*
		(109.1)	(132.6)
K	−1459.0	−9033.1*	−11776.4**
	(2177.8)	(3688.8)	(4444.7)
σ_L	65 ***	67 ***	67 ***
	(12)	(13)	(13)
σ_A	22297*	17160***	18000***
	(11421)	(4440)	(4650)
ρ			−0.120*
			(0.051)
log likelihood	−2604.523	−2584.929	−2584.411
N	430	430	430

Significance levels : * 0.10 ** 0.01 *** 0.001

Table 4. Structural Parameter Estimates for Woody Crops with and without Heckman Sample Selection Correction

	Model		
Heckman Correction	No	No	Yes
Parameter	(3)	(4)	(5)
$\frac{1}{\phi(\sigma_p^2+\sigma_c^2-2\rho\sigma_p\sigma_c)}$	0.22***	0.10**	0.10**
	(0.027)	(0.032)	(0.032)
$\frac{\sigma_c^2-\rho\sigma_c\sigma_p}{\sigma_p^2+\sigma_c^2-2\rho\sigma_p\sigma_c}$	0.020***	0.010*	0.0099*
	(0.0060)	(0.0039)	(0.0039)
b		278.8*	290.2*
		(122.7)	(125.6)
K	−6447.1***	−13257.0***	−13676.9***
	(1219.0)	(2946.6)	(3013.4)
σ_L	36.2***	36.2***	36.2***
	(4.5)	(4.5)	(4.5)
σ_A		16122***	16288***
		(3177)	(3150)
ρ			−0.019
			(0.013)
log likelihood	−1818.258	−1825.603	−1825.583
N	430	430	430

Significance levels : * 0.10 ** 0.01 *** 0.001

The findings show that agricultural landowners would be willing to diversify production with perennial bioenergy crops if financially competitive but only on a portion of their land. Estimation of the structural model shows that agricultural landowners perceive a significantly higher risk to perennial bioenergy production than their current crops. However, even with high capital investment costs, agricultural landowners would be willing to produce perennial bioenergy crops as a result of non-pecuniary benefits.

These results have implications for perennial bioenergy supply. Many perennial bioenergy supply models use a simplifying assumption that farmers are risk neutral (i.e., they grow only the crop with the higher returns) or that returns are risk free. Results from our research suggest that if perennial bioenergy crops are financially competitive, farmers will grow both crops. Farmers will only grow perennial bioenergy crops on a small portion of their land due to the subjective risks of perennial bioenergy production. Therefore, the perennial bioenergy supply models which assume risk neutrality or risk free returns overestimate perennial bioenergy supply. In addition, many bioenergy production plant models assume high rates of conversion within the supply shed. Our results suggest that conversion rates will be low and therefore the supply shed will need to be larger. A larger search radius will increase the transportation costs.

The results also have implications for the impact of policies to promote perennial bioenergy crops. The subjective risks for perennial bioenergy crops are an order of magnitude greater than the landowners current risks. Therefore, policies that only address the expected returns without reducing the risk will have minimal impact at the intensive margins. Bioenergy policies must address the risks associated with perennial bioenergy in addition to the returns to have a significant impact on production. Policies that reduce risk may only need to be temporary until private insurance, contracts, futures markets and risk management strategies are developed.

Finally, this research presents a methodology for modeling choice under risk when the agent has a discrete and continuous choice to make. By applying a structural model we are able obtain a richer understanding of the determinants of those choices. This methodology can be applied to many fields.

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Minnesota Agricultural Landowner Survey of Energy Crops

Dear Landowner,

The United States has set goals to significantly increase the amount of electricity, thermal energy, and biofuels made from renewable sources. One important source is perennial plants grown on farmland. The Center for Integrated Natural Resources and Agriculture at the University of Minnesota is collecting information from farm landowners regarding their attitudes and opinions towards perennial energy crops.

You do not need to have any expertise in farming, farm the land yourself or even have heard of perennial energy crops to successfully complete this survey.

The survey is intended for the **owner** of farmland in Minnesota. Your individual responses will be completely confidential and anonymous. No individual responses will be reported. The survey will take between 15-20 minutes to complete.

Please return the questionnaire in the enclosed, self-addressed, postage-paid envelope within 10 days of receipt. Once we have received your completed questionnaire, your name and any identifying information will be deleted from our database.

Survey # 130

If you have any questions or concerns, please contact me at (612) 624-4299 or email me at curre002@umn.edu. Thank you in advance for participating in this important project.

Sincerely,

Dean Current, Ph.D.
Project Leader

1

Landowner and Land Use Profile

1. What is the total acreage of farmland your household owns, leases, and/or farms regardless of location or use?

	Total Acres
Land I Own	______________
Land I Lease/sharecrop **TO** others	- ______________
Land I rent/sharecrop **FROM** others	+ ______________
Total Land I Farm	= ______________

2. How long have you or your immediate family owned your farmland?

______________ Years

3. What current uses are made of the farmland that you OWN, regardless of whether or not you farm it? *Please indicate the total acreage. If you rotate crops please indicate average acreage per year.*

Acres	Acres
_______ Corn	_______ Confined livestock
_______ Soybeans	_______ Short rotation woody crops
_______ Wheat, oats, and other small grains	_______ Orchards
_______ Sugar beets	_______ Native prairie
_______ Alfalfa	_______ Wetland
_______ Hay—not including alfalfa	_______ Wildlife habitat
_______ Pasture livestock	_______ Recreation—such as hunting, bird watching
_______Vegetables	_______ Other___________________________________

4. What is the average rental rate for land that you own? *If you don't rent out your land please estimate based on rental rates in your area.*

Cropland	$_____________ Acre/Year	___ Don't Know
Pastureland	$_____________ Acre/Year	___ Don't Know

5. Have you ever implemented any of the following programs or practices on your land? *Please circle the number corresponding to your answer.*

	Yes	No	Don't Know
Conservation easement such as Conservation Reserve Program (CRP)	1	2	9
Government conservation program that conserves natural resources while farming such as the Conservation Security Program (CSP)	1	2	9
Soil conservation practice such as no-till/low-till, direct seeding, nutrient management	1	2	9

6. Everyone has different plans for how their land will be used in the future. How likely are each of the following situations to occur <u>within the next ten years</u>? *Please circle the number that fits each situation the best.*

	Highly Unlikely	Somewhat Unlikely	Somewhat Likely	Highly Likely	Don't Know
Land will be operated by family member(s)	1	2	3	4	9
Land will be inherited by family member(s)	1	2	3	4	9
Land will be sold for agricultural use	1	2	3	4	9
Land will be sold for a non-agricultural use	1	2	3	4	9
Land will be rented	1	2	3	4	9
Land will be used for recreation	1	2	3	4	9
Land will be taken out of production and used for conservation	1	2	3	4	9
I will diversify the current use(s) of my land	1	2	3	4	9
I will reduce the current use(s) of my land	1	2	3	4	9
I will maintain the current use(s) of my land	1	2	3	4	9
I will cease to use my land	1	2	3	4	9
I will grow a different crop	1	2	3	4	9

7. Which of the following best describes your awareness about the using <u>perennial crops</u> grown from farmland for energy production before receiving this survey?

	No Awareness	Little Awareness	Some Awareness	High Awareness
Perennial Grasses	1	2	3	4
Trees	1	2	3	4

3

Fast Facts about Perennial Grasses, Legumes and Forbs

- High yielding, drought tolerant, and requires lower fertilizer and herbicide quantities compared to row crops
- Once planted, needs to be re-planted only once every 10 years in early spring
- No-till practices can be used
- Harvested annually in late fall or early spring after nutrients have returned to the roots
- Less time to manage throughout plant's life cycle
- Harvested using conventional haying equipment

Fast Facts about Trees

- Requires lower fertilizer and herbicide quantities compared to row crops
- Harvested between 3 and 12 years after planting
- Once established, can be harvested for 20-30 years without any root disturbance or replanting
- Less time to manage throughout plant's life cycle
- Harvested using standard forestry equipment

What are the Benefits of Perennial Energy Crops?

- Adds organic matter to soils
- Reduces erosion
- Improves water quality
- Provides wildlife habitat
- Sequesters carbon from atmosphere

Attitudes and Perceptions

8. Please indicate the extent to which you agree or disagree with the following statements. *Circle the number that corresponds with your opinion.*

	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree	Don't Know
I am concerned with the quality of my farm soil	1	2	3	4	9
I am concerned with the effect my land has on water quality	1	2	3	4	9
I believe it is important to provide habitat for wildlife on my land	1	2	3	4	9
Growing perennial energy crops could improve water quality in my area	1	2	3	4	9
Growing perennial energy crops could provide wildlife habitat on my land	1	2	3	4	9
Diversifying my production will reduce financial risk on my farm	1	2	3	4	9
If I were to grow perennial energy crops I would be perceived as a land steward by my peers	1	2	3	4	9
The United States should increase domestic sources of renewable energy	1	2	3	4	9
Farmland should be used to increase the United States' energy independence	1	2	3	4	9
I have a responsibility to conserve the land for use by future generations	1	2	3	4	9

9. Assuming growing perennial crops for energy production was financially competitive with your current use, how would you rate your current level of interest?

	No Interest	Little Interest	Some Interest	High Interest
Perennial Grasses	1	2	3	4
Trees	1	2	3	4

10. Below is a list of potential barriers a landowner might encounter when considering growing perennial crops, both grasses and trees. To what degree would each of the following factors limit your willingness to grow perennial crops for energy? *Circle the number that corresponds with your opinion.*

Potential Barrier	Highly Limiting	Moderately Limiting	Slightly Limiting	Not Limiting	Don't Know
A lapse in income until first harvest	1	2	3	4	9
Risk of unsuccessful establishment	1	2	3	4	9
Lack of access to proper equipment	1	2	3	4	9
Risk involved with growing a new crop	1	2	3	4	9
Cost to establish	1	2	3	4	9
Lack of financial assistance	1	2	3	4	9
Lack of information about growing crop	1	2	3	4	9
Lack of renter or contract service provider	1	2	3	4	9
Necessity to learn new skills	1	2	3	4	9
Opinion of my family and friends	1	2	3	4	9
Spending time to learn about a different system	1	2	3	4	9
Having to sign a contract with the government	1	2	3	4	9
Having to sign a contract with an energy producer	1	2	3	4	9
Having to complete paperwork involved with program	1	2	3	4	9
Loss of base acreage eligible for government subsidies	1	2	3	4	9
Loss of bank loan eligibility for converted acres	1	2	3	4	9
Working with government technical assistance	1	2	3	4	9
Current renter not interested	1	2	3	4	9

11. Below is a list of potential barriers a landowner might encounter when considering growing <u>trees</u> specifically. To what degree would each of the following factors limit your willingness to grow trees for energy? *Circle the number that corresponds with your opinion*

Potential Barrier	**Highly Limiting**	**Moderately Limiting**	**Slightly Limiting**	**Not Limiting**	**Don't Know**
Long delay till first harvest (3-12 years)	1	2	3	4	9
Access to equipment for harvesting	1	2	3	4	9
Having tree roots and stumps in tillable land	1	2	3	4	9
Long term commitment for the land (20-30 years)	1	2	3	4	9

12. If growing <u>perennial energy crops</u> was financially competitive with your current practice and there was an energy buyer, which financial arrangements you would prefer, assuming annual net farm income is the SAME under all arrangements? *Rank* ***all*** *of the following choices 1-5 with 1 being your top choice and 5 being your bottom choice. Rank perennial grasses and trees separately.*

	Perennial Grasses	**Trees**
A. Planting, maintenance, and harvest would be my own responsibility and I would be paid for biomass crop upon delivery.	________	________
B. A portion of the cost of planting would be covered; I would receive an **annual payment** for the **first 5 years**; maintenance and harvest would be my own responsibility; I would be paid for biomass crop upon delivery.	________	________
C. 10 year easement for which I would receive an **annual payment**; planting, maintenance, and harvest would be my responsibility; I would also be paid for biomass crop upon delivery.	________	________
D. 10 year easement for which I would receive an **annual payment**; planting, maintenance, and harvest would be the responsibility of a **contract service provider** that I hire; I would be paid for biomass crop upon delivery.	________	________
E. 10 year or longer rental agreement with contract service provider; establishment, maintenance, and harvest would the responsibility of **contract service provider**; I would be paid an **annual rental payment**.	________	________

13. If your annual net farm income from growing <u>perennial grasses</u> was $100 per acre LOWER than your current annual net farm income per acre would you grow <u>perennial grasses</u> on at least some of your land? *Net farm income is total farm revenue minus all farm costs and expenses.*

☐ Yes ⟶ How many acres would you grow at this net farm income? ______________acres
☐ No

14. If your annual net farm income from growing <u>trees</u> was the SAME per acre as your current annual net farm income per acre would you grow <u>trees</u> on at least some of your land? *Net farm income is total farm revenue minus all farm costs and expenses.*

☐ Yes ⟶ How many acres would you grow at this net farm income? ______________acres
☐ No

15. If the particular perennial crop you were considering growing was known to be a noxious or invasive weed (causes or is likely to cause environmental harm) how would you answer question 13 and 14?

Question 13-Grasses

☐ Yes _________acres
☐ No

Question 14-Trees

☐ Yes _________acres
☐ No

16. If you were to grow perennial energy crops which type of farmland would you target for establishment? *Please check all that apply.*

☐ Sandy soils
☐ Poorly drained soils
☐ Land near a lake, river or stream
☐ All my land
☐ Poor quality soil
☐ Sloped land
☐ Most productive land

Land Tenure

17. Which of the following best describes your farming operation? *Please check one*

☐ I own and operate my own land (***Please skip to question # 24***)
☐ I have a one year lease and receive cash rent
☐ I have a multiple year lease and receive cash rent
☐ I have a share cropping arrangement
☐ Other_______________________________________

If selected please answer questions 18 through 23

18. How long have you had your current renter/sharecropper?

__________ years

19. Is your current renter/sharecropper an immediate or extended family member?

☐ Yes ☐ No

20. Are conservation practices mentioned in your lease or lease supplement?

☐ Yes ☐ No (***Please skip to question # 21***)

Please check all below that apply.

☐ No-till
☐ Specific crop rotation
☐ Perennial crop
☐ Conservation drainage
☐ Conservation Reserve Program
☐ Environmental Quality Incentives Program
☐ Other: _____________________________
☐ Precision planting
☐ Planting or maintenance of buffers
☐ Cover crop_______________
☐ Pasture management______________
☐ Conservation Stewardship Program
☐ Re-Invest in Minnesota

21. Have you discussed conservation practices with your current renter?

☐ Yes Who initiated the discussion?

☐ No What is keeping you from initiating this conversation?

22. Would you like to incorporate conservation practices into your lease with your renter?

☐ Not Interested ☐ Little Interest ☐ Some Interest ☐ High Interest ☐ N/A

23. People have different approaches when making decisions about their land. How well do you agree with the following statements? *Please circle number that corresponds with your opinion.*

	Highly Disagree	Somewhat Disagree	Somewhat Agree	Highly Agree	Don't Know
The renter makes most of the decisions about the type of crops grown	1	2	3	4	9
The renter makes most of the decisions about tillage practices	1	2	3	4	9
I make the decisions about conservation on my land	1	2	3	4	9
My renter farms the land the way I want it to be farmed	1	2	3	4	9
I encourage my renter to utilize soil conserving practices	1	2	3	4	9
I can freely discuss the use of different practices with my renter	1	2	3	4	9
The type of relationship I have with the renter strongly influences decisions made about the farm	1	2	3	4	9
The length of my relationship with the current renter strongly influences decisions made about the farm	1	2	3	4	9
My renter's opinion significantly influences decision made about the farm	1	2	3	4	9

Landowner Information

24. Are you a

☐ Male ☐ Female

25. Your age

________years old

27. Does anyone in your household work off-the-farm?

☐ Yes ☐ No

26. Which of the following best describes your farming status? *Please check one.*

☐ I am a full-time farmer
☐ I am a part-time farmer
☐ I am a retired farmer
☐ I am a retired non-farmer
☐ I am a non-farmer
☐ Other________________

28. Is your permanent home located on your farmland?

☐ Yes, my home is located on my land
☐ No, I live within 30 miles from my land
☐ No, I live between 31 and 150 miles from my land
☐ No, I live between 151 and 300 miles from my land
☐ No, I live more than 300 miles from my land

30. What is highest level of formal education you have completed?

☐ Some High School or Less
☐ Technical/Community College Degree
☐ High School/GED
☐ Bachelor's Degree
☐ Some College
☐ Graduate/Professional Degree

31. What was your total annual household income from all sources, before taxes, in 2009?

☐ less than $25,000
☐ $75,001-$100,000
☐ $25,001-$50,000
☐ $100,001-$150,000
☐ $50,001-$75,000
☐ more than $150,000

32. What was your net cash farm income from farm operations in 2009, including rental income?

☐ Less than $0 (Net Loss)
☐ $10,001-$25,000
☐ $0-$5,000
☐ $25,001-$50,000
☐ $5,001-$10,000
☐ more than $50,000

33. What was your debt ratio (total debts divided by total assets) in 2009?

☐ 0-15%
☐ 45-60%
☐ 15-30%
☐ 60-80%
☐ 30-45%
☐ 80-100%

34. We will be conducting in-person and phone interviews with landowners to further understand their thoughts about perennial energy crops. Would you be interested in participating?

☐ Yes ☐ No

If **yes**, what is your:

phone number:_______________________________

email:______________________________________

Is there anything else you would like to share with us?

Thank you for taking the time to complete this questionnaire!

Please return this form using the prepaid, self-addressed envelope.

If you have any questions regarding the study, please feel free to contact us.

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