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Research paper

Willingness to produce perennial bioenergy crops: A contingent supply approach☆

David J. Smith[a,*], Dean Current[b], Candi Schulman[b], K. William Easter[c]

[a] USDA, Economic Research Service, 355 E Street SW, Washington, DC 20024, USA
[b] University of Minnesota, Center for Integrated Natural Resource and Management, Department of Forest Resources, 1530 Cleveland Avenue North, St. Paul, MN 55108, USA
[c] University of Minnesota, Department of Applied Economics, 1994 Buford Avenue, St. Paul, MN 55108, USA

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ABSTRACT

In order to reduce economic and national security risks, U.S. energy policy, in 2005 and 2007, mandated production of renewable biofuels. By 2010, the renewable biofuel industry was consuming approximately one-third of domestic corn and soybean production. To meet this growing demand, conservation and pastureland has been cultivated with corn and soybean, resulting in a reduction in ecosystem services. Perennial bioenergy crops (e.g., switchgrass) offer a more sustainable alternative. However, unlike annual crops, farmers and landowners have little experience with perennial bioenergy crop production. Uncertainty in production and prices may impact the supply of these novel crops into an emerging market. Using a contingent supply method, we show that agricultural landowners are willing to produce perennial bioenergy crops, given competitive returns, but only on a portion of their land.

1. Introduction

In order to reduce economic and national security risks, United States energy policy has included provisions to increase energy independence. Federal policies, such as the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007, and state policies, such as renewable portfolio standards, have been effective at increasing domestic bioenergy production. Renewable liquid fuel has been primarily produced using corn and soybeans, resulting in major changes to the agricultural sector. By 2010, the renewable biofuel industry was consuming approximately one-third of domestic corn and soybean production [1]. To meet this growing demand, conservation and pastureland has been cultivated with corn and soybean [2–5], resulting in a reduction in ecosystem services, such as carbon storage, wildlife habitat and water quality [6,7].

Perennial bioenergy crops (e.g. switchgrass and woody crops) offer an alternative feedstock for producing renewable liquid fuel. These crops have fewer negative environmental impacts than corn and soybeans. Planting perennials for bioenergy would reduce soil erosion, greenhouse gas emissions, and nutrient delivery to water bodies [8,9]. In regions that are dominated by annual crops, some reversion to perennial vegetation is necessary to meet water pollution limits, even with wide-scale adoption of annual crop conservation practices [10].

In order for perennial bioenergy crops to contribute to energy independence and environmental goals, the cellulosic industry must overcome several challenges. Cellulosic ethanol production plants must become more efficient and production cost must decrease. In addition, a consistent supply of low cost biomass must be produced from agricultural land [11]. Unlike crop residues, which come from well established production systems and are readily available in large quantities, perennial bioenergy cropping systems are largely unknown to farmers and landowners. Therefore, the supply of perennial bioenergy crops is dependent on the willingness of farmers to produce these crops.

This study evaluates the willingness of agricultural landowners to produce two major groups of perennial bioenergy crops — grasses (e.g. switchgrass and miscanthus) and woody crops (e.g. willow and poplar). A distinction has been made between these two groups because of the major differences in the agronomics, harvest frequency, stand life, and machinery used for production. Grasses are harvested annually using common harvesting equipment. Woody crops are harvested every three or more years and require different machinery than that used for baling hay. Differences also exist among perennial bioenergy crops within these groups, such as poplar and willow (woody crops) and switchgrass or miscanthus (grasses), but are minor when compared to the difference between woody crops and grasses.

☆ The views expressed are those of the author(s) and should not be attributed to the Economic Research Service or USDA.

* Corresponding author.
E-mail address: david.j.smith2@ers.usda.gov (D.J. Smith).

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With the lack of an existing market in which farmers can reveal their preferences by their perennial bioenergy production decisions, this study uses a contingent supply method that randomly assigns relative net farm incomes for grasses and woody crops. Assignment of relative, as opposed to absolute net income amounts is used to control for the heterogeneity of net farm incomes and to make the results of this study valid beyond just the year of the survey. Previous perennial bioenergy supply approaches have also used randomly assigned absolute and relative net incomes [12,13] to understand the value of bioenergy crop characteristics.

2. Methods

We estimate the willingness of agricultural landowners to supply perennial bioneregy crops using a contingent supply method were we vary levels of net farm income relative to the landowner's current net farm income. Landowners lack sufficient information, such as perennial bioenergy yields and costs, to reliably choose amongst alternatives if only given perennial bioenergy prices. Relative net farm incomes are the net farm income from perennial bioenergy crops minus the current net farm income (i.e. opportunity cost of the land). If landowners were willing to grow perennial bioenergy crops, they were then asked how many hectares they would grow at this relative net farm income. The same set of questions were also asked for woody crops. This resulted in four responses (i.e., two yes/no and two land areas) and two treatments (i.e., relative net farm income of woody crops and grasses) for each respondent. The relative income amounts ranged from -$247 (-$100) to $618 ($250) per hectare (acre) for grasses and -$124 (-$50) to $741 ($300) per hectare (acre) for woody crops in $124 ($50) increments, for a total of eight treatment levels.

2.1. Survey

The experimental design resulted in sixty-four different versions of the survey (i.e. eight treatment levels for two treatments). The survey targeted agricultural landowners in nine counties in the lower Minnesota River Valley, Minnesota. The counties include Blue Earth, Brown, Carver, Le Sueur, Martin, Nicollet, Scott, Sibley, and Watonwan. This population was chosen because they are adjacent to an existing bioheat and biopower plant and a potential biomass plant site. 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 8 ha, 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. The final study population consists of 13,850 agricultural landowners in the nine counties.

2.2. 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 at the 95% confidence level. This is a margin of error (B) of 5% and a Z-score (C) of 1.96. 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 equation for the minimum final sample size is

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

The final sample size needed to be at least 374 agricultural landowners. 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.

2.3. Mail survey administration

The survey used the standard five-contact Dillman mail survey method [14]. 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 them to receive the survey. Then, 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 one or 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.

2.4. Model

Each landowner in our sample received a randomized set of two relative net farm incomes. The farmland owners were asked to answer four questions related to their willingness to grow perennial bioenergy crops. The two area questions were only asked if farmer responded that they were willing to grow perennials. With more than one response variable, multivariate multiple regression (MMR) techniques have advantages over estimating four independent regressions. These include increases in estimation efficiency without loss of consistency, limits in type I errors by consolidating hypotheses testing, and the ability to test hypotheses across response models [15].

Based on the design of our stated choice approach, we use a sample-selection mixed-process MMR estimated by simulated maximum likelihood. The area responses are only observed for those respondents who are willing to grow perennial bioenergy crops. Due to this self selection, it would not be reasonable to assume that the sample of area responses that we received is a random sample of the population. Therefore we estimate a sample selection model. The binary (Yes/No) responses (y_G, y_T) are the selection for the area response (y_g, y_t). In order to identify the parameters in the area equations, the Heckman sample selection model requires that the independent variables (x) in the area equation (x^1) be a subset of the selection equation independent variables (x^1, x^2) [16]. The four equations that we estimate are

$$\begin{aligned} y_G &= \beta_G^1 x^1 + \beta_G^2 x^2 + \varepsilon_G \\ y_g &= \beta_g^1 x^1 + \varepsilon_g \\ y_T &= \beta_T^1 x^1 + \beta_T^2 x^2 + \varepsilon_T \\ y_t &= \beta_t^1 x^1 + \varepsilon_t. \end{aligned} \tag{2}$$

Our model is then, $Y = (1\{y_G > 0\}, y_g, 1\{y_T > 0\}, y_t)'$. We assume that the error term has a joint normal distribution, $\varepsilon = (\varepsilon_G, \varepsilon_g, \varepsilon_T, \varepsilon_t)' \sim \mathcal{N}(0,\Sigma)$. The co-variance matrix is

$$\Sigma = \begin{bmatrix} 1 & \sigma_{Gg} & \sigma_{GT} & \sigma_{Gt} \\ \sigma_{Gg} & \sigma_{gg} & \sigma_{gT} & \sigma_{gt} \\ \sigma_{GT} & \sigma_{gT} & 1 & \sigma_{Tt} \\ \sigma_{Gt} & \sigma_{gt} & \sigma_{Tt} & \sigma_{tt} \end{bmatrix}, \tag{3}$$

where the variance of the discrete equations is equal to one, σ is the co-variance, and σ_{gg} and σ_{tt} are the variances of the area equations. The above regression model is estimated in Stata with the user written command cmp [17].