**Analysis of Factors Affecting Farmers' Willingness to Adopt Switchgrass Production**

by

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***Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Corpus Christi, TX, February 5-8, 2011***



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This research was funded in part by a grant from USDA NIFA as part of the former National Research Initiative Competitive Grants Program.

## Abstract

In the United States, biomass is the largest source of renewable energy accounting for over 3 percent of the energy consumed domestically and is currently the only source for liquid, renewable, transportation fuels. Continued development of biomass as a renewable energy source is being driven in large part by the Energy Independence and Security Act of 2007, which mandates that by 2022 at least 36 billion gallons of fuel ethanol be produced, with at least 16 billion gallons being derived from cellulose, hemi-cellulose, or lignin. However, the market for cellulosic biofuels is still under development. As such, little is known about producer response to feedstock prices paid for dedicated energy crops. While there have been some studies done on factors that determine farmers' willingness to produce switchgrass, these have been very regional in nature. This study will provide information regarding potential switchgrass adoption by agricultural producers in twelve southeastern states. The objectives of this research are 1) to determine the likelihood of farmers growing switchgrass as a biomass feedstock and the acres they would be willing to devote to switchgrass production and 2) to evaluate some of the factors that are likely to influence these decisions, including the price of switchgrass.

## Introduction

In the United States, biomass is the largest source of renewable energy accounting for over 3 percent of the energy consumed domestically and is also currently the only source for liquid renewable fuels used in transportation (Perlack et al. 2005). The continued development of biomass as a renewable energy source is being driven in large part by Renewable Fuel Standard (RFS) enacted as part of the broader Energy Independence and Security Act of 2007 (EISA). The RFS mandates that by 2022 at least 36 billion gallons of fuel ethanol be produced in the United States, with at least 16 billion of these gallons being derived from cellulose, hemi-cellulose, or lignin (U.S. Congress 2007).

There are a number of reasons for promoting the production of ethanol from cellulosic materials. Corn, which is also used for both animal feed and human consumption, is unlikely to be grown in sufficient quantities to meet the feedstock demand for biofuels or to be able to displace current transportation fuels to any significant extent (Hahn-Hagerdal et al. 2006). There are also environmental benefits to the production of biofuels from cellulose as opposed to corn. Perennial cellulosic energy crops have been shown to reduce erosion and require less fertilizer, pesticides, and herbicides than traditional row crops such as corn (Bransby 2005). In addition, the production of cellulosic biofuels is likely to lead to a greater reduction in greenhouse gases than the production of corn-based ethanol (Wang 2008).

Large scale production of dedicated energy crops will be required for cellulosic biofuels to be produced in sufficient quantities to have a significant impact on the mix of energy inputs used in the United States. However, a major hurdle to overcome is the lack of an established market for cellulosic biomass feedstock. For a cellulosic feedstock market to develop producers will have to be willing to plant dedicated energy crops on a large scale and cellulosic ethanol refineries will have to be available to purchase and convert the biomass to biofuel. Because of the high cost associated with the transportation of biomass the area from which a bio-refinery would feasibly be able to draw feedstock would likely be limited, possibly to a 25 mile radius around the plant (Mitchell, Vogel, and Sarath 2008). Thus, producer willingness to grow cellulosic feedstock will be a critical factor in bio-refinery siting decisions. Producer willingness to grow cellulosic feedstock will be a function of numerous factors including the amount and variability of feedstock profits, in both absolute terms and relative to profits from crops traditionally grown in the area (Larson et al. 2005).

The cellulosic feedstock that this study focuses on is switchgrass. Switchgrass is a fast-growing perennial grass that is native to North America. Switchgrass has the capability to produce high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003) meaning that switchgrass could be grown on marginal lands not currently be used to produce food or fiber. Switchgrass has appeal for planting on conservation lands to reduce erosion due to its extensive root system and canopy cover (Ellis 2006). Switchgrass' deep root system also allows it to sequester more carbon in the soil than many traditional row crops (Ma, Wood, and Bransby 2000).

While there have been some studies done on factors that determine farmers' willingness to produce switchgrass (e.g. Jensen et al. 2007; Bransby 1998; Wen et al. 2005), these studies have been regional in nature and more research considering different geographical areas and variables is needed for those involved with switchgrass and bio-energies to gain a broader perspective.

Thus, the objectives of this study are to analyze the willingness of producers in the southeastern United States to plant switchgrass as a biofuel feedstock and to estimate the area of switchgrass they would be willing to plant at different switchgrass prices. The study will also evaluate the factors that influence a producer's decision to convert acreage to switchgrass, including on and off-farm income, current farming activities, and a variety of other farm and farmer characteristics.

## Review of Literature

### *Empirical Adoption Studies*

The literature on the adoption of new crops and technologies varies widely in its focus from the adoption of fertilizers by rice farmers in Côte d'Ivoire (Adesina 1996) to the decision by farmers to adopt soil conservation practices in Virginia (Norris and Batie 1987). Despite the variety of circumstances included in these studies, there are a number of factors that consistently appear to have a significant influence on adoption decisions. These factors include a variety of farmer and farm characteristics.

*Farmer Characteristics*

Age and education of the decision maker are often taken into account when determining the willingness to  adoption new agricultural technologies.  Older producers may not have as long a planning horizon over which to recoup the benefits of investing in the technology when compared with younger decision makers.  More highly educated producers may be better able to discern the benefits of a new technology relative to less educated farmers.

Previous studies have shown that age of the decision maker has a negative effect on the willingness to adopt new technologies or innovations (e.g. Daberkow and McBride 1998;

Norris and Batie 1987). However, at least one study (Jensen et al. 2007) has shown age not to be a significant factor in the adoption decision with respect to potential production of switchgrass. There are several examples in the relevant literature showing that attaining a higher level of education has a positive effect on innovation adoption (Nkonya, Schroeder, and Norman 1997; Jensen et al. 2007; Norris and Batie 1987; Baidu-Forson 1999).

Off-farm and on-farm income of the decision maker are factors that have been analyzed by many adoption studies. The effect of off-farm income on innovation adoption is analyzed by many researchers including  Jensen et al. (2007); Adesina (1996); Norris and Batie (1987); and Fernandez-Cornejo, Hendricks, and Mishru (2005). Jensen et al. (2007) found off- farm income to have no effect on the land area devoted to switchgrass production . By comparison, Norris and Batie (1987) found off-farm income to have a negative effect on conservation practice expenditures and Fernandez-Cornejo, Hendricks, and Mishra (2005) found it to have a positive effect on adoption of integrated pest management practices.

The effects of on-farm income's innovation adoption have been analyzed by researchers such as  Jensen et al.( 2007) and  Norris and Batie (1987). Jensen et al. (2007) found on-farm income per unit of crop area to have a negative effect on potential area of switchgrass grown for energy production, perhaps due to the increased opportunity cost of converting hectares to switchgrass. However, Norris and Batie (1987) found that income had a positive effect on the adoption of new conservation techniques.

Multiple studies have analyzed the way that risk effects adoption of innovation (e.g., Fernandez-Cornejo, Beach, and Huang 1994; Daberkow and Mcbride 1998; Fernandez-Cornejo, Daberkow, and McBride 2001; Marra, Pannell, and Ghadim 2003). These studies have found that early adopters tend to be less risk adverse than late adopters or those that never adopt the innovation. Daberkow and McBride (1998) describe late and non-adopters as those who perceive a large amount of production and financial risk associated with an innovation.

*Farm Characteristics*

Many studies focusing on adoption have shown that farm size has a positive effect on the adoption and extent of adoption of an agricultural innovation (e.g., Nkonya, Schroeder, and Norman 1997; Daberkow and McBride 1998; Adesina 1996; Ransom, Paulyal, and Adhikari 2003). However, Jensen et al. (2007) found that farm size did not have an impact on potential land area converted to switchgrass in Tennessee. Feder, Just, and Zilberman (1985 p.273) suggest caution when using farm size as an explanatory variable because it can be a "surrogate for a large number of potentially important factors such as access to credit, capacity to bear risks, access to scarce inputs, wealth, access to information, and so on."

Land tenure is another key factor in the decision to adopt new agricultural technologies (e.g., Fernandez-Cornejo, Beach, and Huang 1994; Fernandez-Cornejo, Daberkow, and Mcbride 2001; Jensen et al. 2007). The results of these studies have shown inconsistencies the effects of leased land on the rate of adoption.

***Switchgrass Survey Studies***

Previous studies based on surveys of actual or potential switchgrass producers include Bransby (1998), Hipple and Duffy (2002), Jensen et al. (2007), Wen et al. (2005), Kelsey and Franke (2009), and Velandia et al. (2010). Most of these studies did not use regression analysis or any explicit theoretical models to evaluate potential adoption of switchgrass production; instead, conclusions were based on sample statistics (e.g. Bransby 1998; Wen et al. 2005;

Kelsey and Franke 2009). Hipple and Duffy (2002) did not make use of any numerical values, instead relying on verbal answers to come to generalized conclusions.

Velandia et al. (2010) conducted a study of switchgrass producers already growing switchgrass under contract in East Tennessee. The study survey examined the producers' perceptions of switchgrass production and their willingness to continue producing switchgrass beyond the expiration of their current contracts. A key finding of this study was that a large percentage of the producers interviewed were willing to continue producing switchgrass after their current contract to produce switchgrass expired. About 44.7% rating their likelihood a 7 on a 7 point scale, while another 36.8 rated their likelihood a 6 out of 7. Producers saw switchgrass as a means to diversify their farm and to allocate their time and resources in the off-season. A limitation of the study is that it looked a small number of producers in a limited geographical area.

Jensen et al. (2007) analyzes willingness to grow switchgrass as a biofuel feedstock using data from a survey of Tennessee farmers. A Tobit model was used to estimate the likelihood and extent to which Tennessee farmers would be willing to grow switchgrass as a biofuel feedstock. Significant explanatory variables that were negatively associated with willingness to grow switchgrass were farm size, the leasing of land, net farm income per unit of crop area, the presence of livestock, age, and concern that the planting period for switchgrass would conflict with the planting period for other crops. Significant variables that were positively associated with willingness to grow switchgrass were the practicing of no-till, the growing of soybeans, education level, the perceived need for technical assistance regarding growing and harvesting switchgrass, concern that markets for switchgrass were still under development, the desire to provide wildlife habitat on their land, the belief that switchgrass harvest limits on Conservation Reserve Program (CRP) land were too restrictive, and willingness to consider sign a long-term contract to grow switchgrass for energy. While this study provided useful insights, the study was geographically limited to one state.

## Data and Modeling

### *Data*

The data used in this study were collected from a mail survey of agricultural producers with at least $10,000 in sales. The survey was sent to 7,000 producers randomly selected by the US Department of Agriculture's National Agricultural Statistics Service from the following states: Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

The initial mailing of the survey included a cover letter explaining its purpose and a postage-paid return envelope. There was a follow-up reminder postcard sent a week after the initial mailing. A follow-up mailing that included a letter emphasizing the importance of the survey, and another copy of the questionnaire was sent two weeks after the mailing of the reminder postcard. A total of 1,322 surveys were returned and recorded for an 18.9 percent response rate.

The five major areas addressed in the survey are: 1) the respondent's knowledge of, and interest in, switchgrass as an energy crop; 2) the respondent's opinion on topics related to switchgrass production as a biomass feedstock, including conversion of acreage in response to a specified switchgrass price; 3) characteristics of the farm operation, including farm size, types of enterprises, and use of various agricultural practices; 4) financial information, including on and off-farm income; and 5) demographic characteristics of the respondents.

After being provided with information about switchgrass, producers' willingness to grow switchgrass was solicited with two questions. First, producers were asked whether they were interested in growing switchgrass as a crop for energy production. This question was included to screen out producers who were unlikely to entertain an offer to grow switchgrass. Producers who expressed some interest in producing switchgrass, were asked to continue to a question asking whether they would be willing to produce switchgrass given a specified farmgate per ton price for switchgrass. Each respondent was randomly assigned one of five different prices - $40/ton, $60/ton, $80/ton, $100/ton, or $120/ton. If the respondent indicated that they would be willing to produce switchgrass at that price, then they were asked how much area of switchgrass they would grow.

***Economic Model***

Several studies have used a Tobit model to analyze crop and innovation adoption (e.g., Baidu-Forson 1999; Rajasekharan and Veerputhran 2002; Adesina 1996; Ransom, Paulyal, and Adhikari 2003; Jensen et al. 2007). In this study, producer unwillingness to grow switchgrass is assumed to have arisen from one of two possible sources - either the farmer was not interested in growing switchgrass at any price or the farmer was interested in growing at some price, but not the price they were offered in the survey. Such a response pattern follows a Tobit specification with a binary sample selection rule. The binary sample selection rule is used to model the variable representing interest/no interest in growing switchgrass, and the Tobit model is used to estimate acreage adoption in response to switchgrass prices and other variables given that the producer is interested in growing switchgrass. The outcomes for INTEREST may take on values of 0 or 1, representing whether the producer is not interested or has some interest in growing switchgrass. If the producer indicates interest (INTEREST=1), then the value for ACREAGE , acres that producers who are interested in growing switchgrass might produce, can take on a value of zero or some positive value. If the producer was not willing to produce at the specified farmgate price they were provided, the value for ACREAGE would be zero. If they were willing to produce acreage at the specified price, the ACREAGE would take on some non-zero value.

Following Cho et. al (2008), INTEREST can be expressed as:

(1) $$INTEREST = 1 \; if \; z'\alpha + u > 0$$
$$= 0 \; if \; z'\alpha + u \leq 0,$$

where *z* is a matrix of opinions about switchgrass, farm characteristics, and farmer demographics, $\alpha$ is a vector of parameters , and $u$ is the vector of errors.

The acreage portion of the model can then be written as:

(2) $$ACREAGE = 0 \; if \; z'\alpha + u > 0 \text{ and } x'\beta + e \leq 0$$
$$= x'\beta + e \; if \; z'\alpha + u > 0 \text{ and } x'\beta + e > 0,$$

where is $x$ is a matrix of switchgrass price, farm characteristics, and farmer demographics, $\beta$ is a vector of parameters , and *e* is a vector of errors.

If there is correlation between the decisions or equations, then the likelihood function can be expressed as (English, 2002, Nawata, 1994, and Greene, 1995):

(3) $$L = \prod_{INTEREST=0}[1 - \Phi(z'\alpha)] \times \prod_{INTEREST=1,ACREAGE=0} \psi\left(z'\alpha, -\frac{x'\beta}{\sigma}; -\rho\right) \times \prod_{INTEREST=1,ACREAGE>0} \frac{1}{\sigma} \phi\left(\frac{ACREAGE - x'\beta}{\sigma}\right) \times \Phi\left(\frac{z'\alpha + \rho(ACREAGE - x'\beta)/\sigma}{(1-\rho^2)^{1/2}}\right).$$

Note that the likelihood contains three distinct components, first is probability that a farmer is not interested, second is probability that a farmer is interested, but will not convert any acreage at the specified price, and third is the acres to be converted among those who are interested and would accept the specified price.

The test for using the Tobit model with sample selection is found by examining the statistical significance of $\rho$. If $\rho$ is not significantly different from zero, then the $\rho$ term drops out of Equation (3), as does $\frac{x'\beta}{\sigma}$ from the second term, and the $z'\alpha$ from the third term. In this case, the model becomes two separate models, a Probit on INTEREST and a Tobit model for ACREAGE. The two likelihood functions are, for the Probit model of INTEREST,

$$(4)\ L = \prod_{INTEREST=0}[1 - \Phi(z'\alpha)] \times \prod_{INTEREST=1} \Phi(z'\alpha),$$

and for the Tobit model of ACREAGE,

$$(5)\ L = \prod_{ACREAGE>0} \left[\frac{1}{\sigma}\, \phi\left(\frac{ACREAGE - x'\beta}{\sigma}\right)\right] \times \prod_{ACREAGE=0} \left[1 - \Phi\left(\frac{x'\beta)}{\sigma}\right)\right].$$

***Hypothesized Effects***

The explanatory variables and their hypothesized signs are displayed in Table 1 along with the means for each. The dependent and explanatory variables are presented according to the stages of modeling, the first representing interest in growing switchgrass and the second representing the number of acres that would be converted to switchgrass by producers with an interest in growing it.

Interest in Growing Switchgrass

INTEREST is hypothesized to be influenced by demographic and farm characteristics as well as producer perceptions of switchgrass and switchgrass production. These are listed in Table 1. Producers were asked how important a number of different factors were to their decision to grow switchgrass. Several of these factors are hypothesized to affect INTEREST. Farmers who perceived a high potential for planting/harvesting time conflicts between switchgrass and other crops (PLANCON), a lack of developed switchgrass markets (MARKCON), a low level of knowledge of production practices for switchgrass relative to other crops (KNOW), and uncertainty about continuing eligibility of land for CRP payments when producing switchgrass (CRPQUAL) are all hypothesized to be negatively associated with interest in growing switchgrass. Given that switchgrass is a perennial crop that has a life span of 10 years or more, the higher the importance that respondents placed on concerns about producing switchgrass on leased land (CONLEASE), the less likely their interest in growing switchgrass. Land ownership is widely believed to encourage adoption of innovation (Fernandez-Cornejo, Beach, and Huang 1994). Further, many of the positive attributes of switchgrass cultivation, such as erosion control and suitability for native wildlife habitat, are captured by the landowner and not the renter. Finally, Jensen et al. (2007) found that producers who leased their land were less willing to convert land to switchgrass production. The importance of the potential to help with national energy security (ENSECURE), the potential environmental benefits associated with producing switchgrass, such as lowering fertilizer and herbicide applications (LINPUT), and the potential for switchgrass to provide wildlife habitat (HABITAT) are each postulated to have a positive influence on interest in growing switchgrass.

Higher education levels (EDUC) are hypothesized to have a positive effect on interest in growing switchgrass. Education was found to positively affect adoption of genetically engineered corn (Fernandez-Cornejo, Daberkow, and McBride 2001) and cotton (Marra, et al. 2001). AGE is a continuous variable representing the farmer's age. Older farmers may have less time to reap the benefits of an investment in a new crop; hence they may also be less willing to try a new crop, especially a perennial such as switchgrass.

It is hypothesized that switchgrass may be sold primarily under contract, therefore, farmers who are experienced in dealing with contract sales may be more interested in growing switchgrass. Thus, CONTRACT, a dummy variable indicating whether a producer has ever sold a commodity under contract, is expected to be positively correlated with interest in growing switchgrass.

Respondents were asked to indicate their level of agreement (1=strongly disagree, …, 5=strongly agree) with the statement that “You are reluctant about adopting new production methods or crops until you see them working for others” (LADOPT). Several studies (e.g. Fernandez-Cornejo, Beach, and Huang 1994; Daberkow and Mcbride 1998; Fernandez-Cornejo, Daberkow, and McBride 2001) have found that early adopters of innovations tend to be less risk adverse than those who choose not to be early adopters. Therefore, it is hypothesized that LADOPT will be negatively correlated with interest in growing switchgrass.

Switchgrass can be harvested with the same farm implements as hay (Jensen et al. 2007). If a farmer already produces hay, reason dictates that they would be more familiar with the process of harvesting grass as a profitable enterprise. Also, they would already either have the equipment necessary for harvest or have a working relationship with a custom harvest service. Jensen et al. (2007) found that producers who had hay equipment had a greater willingness to grow switchgrass. Hence, it is hypothesized that HAYEQUIP, a dummy variable that takes the value of one if the producer owns hay equipment and a value of zero if not, will have a positive effect on interest in growing switchgrass.

Switchgrass production may compete with cattle grazing for pasture acreage and other lands suitable to its production (Griffith, 2009). Also, switchgrass may have to compete with the production of other established types of grasses that are used conventionally for hay.

Therefore BEEF, a dummy variable that takes a value of one if the producer raises beef cattle and zero if not,  is hypothesized to have a negative effect on the adoption of switchgrass.

Farm income is represented by FINCLT10, FINC1030, and FINC3050, which represent 2008 farm incomes of less than $10,000, $10,000 to $29,999, and $30,000 to $49,999, respectively. Higher farm incomes could mean that farmers may feel comfortable trying a new crop such as switchgrass.   Daberkow and McBride (1998) found a positive relationship between the probability of precision agriculture adoption in corn and farm incomes.  Hence, compared with the omitted income category of $50,000 or greater, the signs on the dummy variables representing the three lower farm income categories are expected to be negative.

Acreage Adoption Among Farmers Interested in Growing Switchgrass

Producers who expressed at least some interest in growing switchgrass were then asked if they would be willing to grow switchgrass at a specified farmgate price and, if so, how much area of switchgrass they would be willing to plant (ACREAGE). If the producer indicated they not convert any acres at the specified price, ACREAGE=0.  If the producer indicated they would adopt switchgrass acreage at the specified price, the value for ACREAGE represented that number of acres.  Each respondent was randomly assigned one of five different prices - $40, $60, $80, $100, or $120 per ton. PRICE is a variable representing the farmgate dollar values per ton producers were hypothetically offered for switchgrass.  Higher prices should be positively associated with the area of switchgrass a producer was willing to produce, because it raises the potential profitability to produce it everything else being equal.

As farm size increases, more land area is hypothesized to be available for conversion to switchgrass.  FARMAC is a continuous variable that reflects the total number of acres the producer had in production in 2008. A basic hypothesis about technology transfer is that the adoption of an innovation will tend to occur earlier on larger farms than on small farms (Fernandez-Cornejo, Daberkow, and McBride 2001).

It is hypothesized that idled land area on the farm (IDLED) will have a positive effect on land converted to switchgrass. The opportunity costs of converting idled land may be relatively low compared with other uses. The effects of having acreage in major row crops (soybeans, corn, cotton, tobacco and wheat) were investigated with dummy variables (SOYD, CORND, COTTD, TOBD, and WHED, respectively) that took the value of one if the producer grew that particular crop in 2008 and zero otherwise.

Off-farm income was represented by a series of dummy variables representing off-farm income of less than $10,000 (OFIL10), off-farm income from $10,000 to $29,999 (OFI1030), and off-farm income from $30,000 to $49,999 (OFI3050). Off farm income increases overall household income, thereby reducing reliance on on-farm income and providing potential income security to try new crops. Also, because switchgrass' perennial nature reduces management intensity (Mclaughlin and Kszos 2005), farmers that are employed off-farm may have higher opportunity costs associated with the time spent on-farm. Fernandez-Cornejo, Hendricks, and Mishra (2005) found a positive relationship between off farm income and agricultural technology adoption focusing on herbicide-tolerant soybeans. As a result, it is hypothesized that OFIL10, OFI1030, and OFI3050 will have negative effects compared with the omitted off-farm category of off-farm income of at least $50,000 per year.

Regional dummy variables were included to investigate the effects of geographic location on acreage conversion. The SWEST dummy variable represented the states in the southwest part of the region (OK,TX), while the MIDS dummy variable represented the states in the mid-south (TN, KY, AR). The omitted regional dummy represents all other states in the study region (AL, GA, LA, MS, NC, SC, VA) These dummy variables were also interacted with farm acreage (FARMAC) to examine the effects of farm acreage on conversion rates varied across regions.

When no-till is used, erosion rates on land can be decreased. A benefit of growing switchgrass is erosion control. Therefore, it is hypothesized that farmers using no-till practices on their lands (NOTILL) may be more willing to adopt switchgrass than farmers not using no-till practices.

**Results**

After deleting observations with missing values for the variables used in the model, a total of 802 observations remained. Of these responses, 67.46% of the farmers expressed interest in producing switchgrass. Therefore, a total of 541 observations were available for the Tobit portion of the modeling.

The rate of 67% of farmers being interested in growing switchgrass across the region can be compared with the 2005 study of Tennessee farmers' interest in growing switchgrass conducted by Jensen, et. al (2005) which found that less than 30% were interested . Also, a 2007 study of farmers in Southern Virginia found that only about 43% were interested in growing switchgrass even if it were profitable (Wen, et al. 2009). Among the farmers interested growing switchgrass, the average number of acres they would convert was 74.85 acres, a greater number than the 67.3 acres per farm in the 2005 Tennessee study by Jensen, et. al. and 67 acres per farm in the Virginia study by Wen, et al.

### *Opinions About Switchgrass*

A comparison of the mean Likert scale importance ratings (1 = not at all important. . . 5 = extremely important) of the factors potentially influencing interest in growing switchgrass is presented in Table 2. These factors are included as explanatory variables in the Probit model of INTEREST. Notably, the two factors with the highest mean importance ratings are concerns that the market for switchgrass was still not yet developed (MARKCON) and the potential for switchgrass to lower input use compared with other crops (LINPUT). The next most important factor is the potential for switchgrass to contribute as a fuel source to increase energy security (ENSECURE). Other factors that are of moderate importance are knowledge about switchgrass production practices compared with other crops (COMPKNOW), capability of switchgrass to provide wildlife habitat (HABITAT), and concerns about land qualifying for CRP after being brought into switchgrass production (CRPQUAL). The factors that are of least importance, on average, to producers are potential conflicts with planting and harvesting periods (PLANCON) and concerns about producing switchgrass on leased land (CONLEASE).

### *Tobit Model with Sample Selection*

Initially, the dependent variables INTEREST and ACREAGE were estimated as a Tobit model with sample selection. The estimated coefficient for $\rho$ was not statistically significant at $\alpha$=.10. These estimates are not reproduced here but are available from the authors.

Given the information above, the model was then re-estimated as a separate Probit on all the observations for INTEREST, and a Tobit with ACREAGE as the dependent variable on those observations for which INTEREST=1. The results for these models and the associated marginal effects are presented in Tables 3 and 4.

### *Probit Model of Producer Interest in Growing Switchgrass*

The estimated Probit model is significant overall, as indicated by the likelihood ratio test comparing it with an intercept only model (LLR(0)). The model correctly classifies nearly 80 percent of the observations and the McFadden's Pseudo $R^2$ is 0.2881. The coefficient for AGE is negative and statistically significant, suggesting that older producers are less likely to be interested in growing switchgrass. As expected, producers with hay equipment were more likely to be interested, while those with beef cattle were less interested. The two highest of the three farm income dummy variables were negative and significant, suggesting that interest in growing switchgrass was lowest among producers with between \$10,000 and \$50,000 of annual on-farm income.

As anticipated, the estimated coefficient and marginal effect for PLANCON and CONLEASE are negative and significantly different from zero. The estimated coefficients for ENSECURE and LINPUT are both positive and significant, as are the marginal effects, indicating producers are influenced by both energy security and environmental or input cost concerns. While the estimated coefficient on MARKCON is significant, its positive sign is unexpected, since as producers are more concerned about the market's development, one would expect them to be less interested in producing switchgrass. This could reflect that market concerns are greater than producers are interested in growing switchgrass. The estimated coefficients for CRPQUAL, HABITAT, and KNOW are not significantly different from zero.

### *Tobit Model of Acres of Switchgrass Producers Willing to Grow*

The Tobit model of INTEREST is significant overall as indicated by the likelihood ratio test (LLR(0)). The estimated coefficient and marginal effects for PRICE are significant and of expected sign. The estimated marginal effect shows that as price is increased by $1 per ton, the acres planted increases by 0.32 acres. The estimated coefficient for total farm acres (FARMAC) is also positive and significant, suggesting that larger farms are willing to grow more acres of switchgrass. The estimated marginal effect on FARMAC, suggests that a one acre increase in total farm size leads to increase the number of acres a producer is willing to grow of 0.0119 acres. Producers who have idled acres (IDLED) were also willing to grow more acres of switchgrass. A producer with idled acres, is willing to grow an additional 32.73 acres of switchgrass. The estimated coefficients on soybeans, cotton, and corn are not significantly different from zero. However, producers who grew tobacco (TOBD) were willing to grow 41.61 less acres of switchgrass than those who did not grow tobacco. On the other hand, producers who grew wheat (WHEATD) are willing to 25.16 more acres of switchgrass than producers who did not grow wheat. The regional dummy variable for the southwestern states (SWEST) is significant and negative, while that for the mid-south (MIDS) is not significantly different from zero. Producers from the southwest were willing to grow an additional 53.53 acres compared to those from the reference region. The coefficient for the interaction between farm size and SWEST is not significant, however the interaction between farm size and MIDS is positive and significant. This result suggests that farm size has a greater effect on the number of acres of switchgrass that producers in the mid-south would be willing to grow than on producers in the reference region. The effects of off-farm income are as expected, with the dummy variables representing lower farm incomes (OFIL10, OFI1030) having negative signs on the estimated coefficients and marginal effects. Compared with farmers having at least $50,000 in off-farm income, farmers with off-farm income of less than $10,000 are projected to produce 37.86 fewer acres, while farmers with off-farm incomes of less than $10,000 are projected to produce 25.51 fewer acres. Farmers using no-till practices (NOTILL) are projected to produce 15.23 acres more than those not using no-till.

**Conclusions**

The results from this study suggest that producers in the survey region are interested in growing switchgrass. The share of producers that are interested in growing switchgrass if profitable appears to be somewhat higher than surveys of the past several years, suggesting that interest may be on the rise. However, this interest appears to be tempered by concerns about potential conflicts with planting and harvest times of other crops and concerns about introducing a new perennial crop such as switchgrass on leased land. Producers are encouraged by the potential to improve the nation's energy security by contributing an alternative fuel feedstock source, and the potential for switchgrass to lower input use. Based on the results above, educational programs for farmers may need to focus on planting and harvest time production management issues, for example allocation of farm labor and equipment in relation to other crops. Educational programs may also emphasize input use changes compared with other crops. In addition, concerns about growing switchgrass on leased land could indicate that lease length and contract length may need to correspond.

As would be expected with a new crop, those who perceived themselves to be "late adopters", or who take a wait-and-see attitude, are less likely to be interested in growing switchgrass (at this time, anyway). As would be expected, older producers are also less likely to be interested perhaps because of the limited timeframe to receive the benefits of the crop. Given this information, producers who are more likely to be interested are those who are more willing to take risks and are more likely to be experienced farmers. Other production management issues also affect interest, in that those with beef cattle are less likely to be interested, perhaps being hesitant to convert current pasture to switchgrass or because of lifestyle or other social factors associated with beef production, while those with hay equipment are more likely to be interested. The results also suggest that interest in growing switchgrass may be lowest among those with moderate farm incomes. A possible interpretation of this result is that higher income farmers may feel they have the resources to risk growing a new crop, while the lowest income farmers may be looking for a more profitable alternative.

The results indicate that among those interested in growing switchgrass, for each dollar increase in the farmgate price of switchgrass, the area of switchgrass a producer is willing to grow would increase. Furthermore, as would be expected, producers with larger farm operations indicated that they would be willing to convert a larger proportion of their land relative to farmers with smaller operations. The results suggest that farmers with idled land are willing to convert more acres, perhaps looking for an alternative use of marginal lands. On the other hand, high cash return crops, such as tobacco, have a negative influence, reflecting the high opportunity cost of converting land. Intra-regional differences were found, with farmers in the southwest willing to convert more area and farmers with larger farm sizes in the midsouth being willing to convert more than those outside these regions. Farmers who already use no-till practices are also willing to convert more land, which may reflect views that switchgrass is a way to decrease input use compared with no-till farmer or may reflect views that, like no-till, switchgrass can help control erosion compared with conventional row crops. This result suggests that switchgrass may be more appealing where there are already concentrated areas of no-till use and may be indicative of a larger proportion of marginal lands in that area.

These results show that in the region, on average, interested producers would be willing to convert about 75 acres. If a yield of 8 tons per acre is assumed, this is about 600 tons per farmer. If a yield of 80 gallons of cellulosic ethanol per ton of switchgrass is assumed, for a 50 million gallon facility, a bio-refinery would require about 625,000 tons per year (Miranowski and Rosburg, 2010). Therefore, a quick estimate is that the bio-refinery would need to contract with about 1,042 farmers. This highlights the logistical issues associated with assembling switchgrass and the importance of improvement of switchgrass yield improvement, densification, pre-processing methods, and conversion efficiency to make commercially scaled facilities tractable. The average price offered to the respondents was about $83 per ton and the results in this study do indicate that for each increase in farmgate price per ton, the amount interested producers will grow increases by about 0.32 acres. Again, if a yield of 8 tons per acre is assumed, the amount of additional switchgrass supplied would be about 2.56 tons. While this research provides insights into switchgrass feedstock supply across the southern U.S., many issues related to the development of switchgrass feedstock supply remain. Examples include contract provisions preferred by relative to preferences by bio-refineries, potential for grower harvest, storage, or assembly cooperatives, economics of pre-processing facilities, and potential farm-level impacts of incentives for growing switchgrass for carbon sequestration purposes.

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Table 1. Variable Names and Definitions

| Variable Name | Definition | Hypothesized Sign | Mean |
|---|---|---|---|
| *Probit Dependent Variable* | | | (N1=802) |
| INTEREST | 1 if producer is interested in growing switchgrass, 0 otherwise | NA | 0.6746 |
| *Probit Explanatory Variables* | | | |
| Opinion Variables, | Level of Importance (1 if not at all important, …, 5 if extremely important) | | |
| PLANCON | Possible conflicts between planting/harvest period for switchgrass and planting/harvest period for your other crops | - | 2.4576 |
| CONLEASE | Concern about planting a perennial crop such as switchgrass on land that is leased | - | 2.1596 |
| ENSECURE | Potential to contribute to national energy security by producing switchgrass for fuel | + | 3.2531 |
| LINPUT | Possibility of lowering fertilizer and herbicide applications as compared with crops currently growing | + | 3.5337 |
| CRPQUAL | Whether acreage converted to switchgrass would qualify for CRP payments or not | - | 2.6097 |
| HABITAT | Potential for switchgrass to provide habitat for native wildlife on your farm | + | 2.9626 |
| MARKCON | Concern that the market for switchgrass as an energy crop is not developed enough yet | - | 3.5387 |
| KNOW | Your knowledge about growing switchgrass compared with your knowledge about growing other crops | - | 2.9838 |
| Farm and farmer characteristics | | | |
| AGE | Age in years | - | 58.5935 |
| EDUC | 1 if elementary or middle school, 2 if some high school, 3 if high school graduate, 4 if some college, 5 if college graduate, 6 if post graduate school | + | 4.1820 |
| CONTRACT | 1 if have produced commodities under contract | + | 0.2431 |
| LADOPT | Level of agreement with statement "You are reluctant about adopting new production methods or crops until you see them working for others" 1 if strongly disagree, …, 5 if strongly agree | - | 3.0811 |
| HAYEQ | 1 if have hay equipment, 0 otherwise | + | 0.6484 |
| BEEF | 1 if produce beef cattle, 0 otherwise | ? | 0.6820 |
| FINCLT10 | 1 if farm income in 2008 less than $10,000, 0 otherwise | - | 0.4152 |
| FINC1030 | 1 if farm income in 2008 $10,000 to $29,999, 0 otherwise | - | 0.3005 |
| FINC3050 | 1 if farm income in 2008 $30,000 to $49,999, 0 otherwise | - | 0.1072 |

Table 1. Continued.

| Variable Name | Definition | Hypothesized Sign | Mean |
|---|---|---|---|
| | | | (N2=541) |
| *Tobit Dependent Variable* | | | |
| ACREAGE | Acres that farmers would be willing to convert to switchgrass | NA | 74.8477 |
| *Tobit Explanatory Variables* | | | |
| PRICE | Price offered for switchgrass at farmgate if transportation of the biomass from the farm is provided, $40, $60, $80, $100, or $120 per ton | + | 82.8096 |
| FARMAC | Acres farmed in 20080 | + | 481.3592 |
| IDLED | 1 if have idled acres, 0 otherwise | + | 0.1405 |
| SOYD | 1 if have soybean acres, 0 otherwise | ? | 0.1867 |
| CORND | 1 if have corn acres, 0 otherwise | ? | 0.1756 |
| COTTD | 1 if have cotton acres, 0 otherwise | ? | 0.0481 |
| TOBD | 1 if have tobacco acres, 0 otherwise | ? | 0.0481 |
| WHED | 1 if have wheat acres, 0 otherwise | ? | 0.1590 |
| SWEST | 1 if located in TX or OK, 0 otherwise | ? | 0.1294 |
| MIDS | 1 if located in TN, KY, or AR, 0 otherwise | ? | 0.2921 |
| SWAC | Interaction between SWEST and FARMAC | ? | 84.4714 |
| MIDSAC | Interaction between MIDS and FARMAC | ? | 102.8244 |
| OFIL10 | 1 if off-farm income in 2008 less than $10,000, 0 otherwise | - | 0.0850 |
| OFI1030 | 1 if off-farm income in 2008 $10,000 to $29,999, 0 otherwise | - | 0.1534 |
| OFI3050 | 1 if off-farm income in 2008 $30,000 to $49,999, 0 otherwise | - | 0.2052 |
| NOTILL | 1 if use no till farming practices, 0 otherwise | + | 0.5416 |

Table 2. Mean Importance Ratings of Influences on Decision to Grow Switchgrass[a]

| | | Mean (1=not at all, …, 5=extremely) N=802 | Std. Error | |
|---|---|---|---|---|
| MARKCON | Concern that the market for switchgrass as an energy crop is not developed enough yet | 3.5387 | 0.0429 | a |
| LINPUT | Possibility of lowering fertilizer and herbicide applications as compared with crops currently growing | 3.5337 | 0.0414 | a |
| ENSECUR | Potential to contribute to national energy security by producing switchgrass for fuel | 3.2531 | 0.0441 | b |
| COMPKNOW | Your knowledge about growing switchgrass compared with your knowledge about growing other crops | 2.9838 | 0.0439 | c |
| HABITAT | Potential for switchgrass to provide habitat for native wildlife on your farm | 2.9626 | 0.0432 | c |
| CRPQUAL | Whether acreage converted to switchgrass would qualify for CRP payments or not | 2.6097 | 0.0487 | d |
| PLANCON | Possible conflicts between planting/harvest period for switchgrass and planting/harvest period for your other crops | 2.4576 | 0.0439 | e |
| CONLEASE | Concern about planting a perennial crop such as switchgrass on land that is leased | 2.1596 | 0.0483 | f |

[a] Like letters indicate means that were not statistically different at the 95% confidence level.

Table 3. Estimated Probit Model of Producer Interest in Growing Switchgrass

| Variable (N=802) | Est. Coeff. | Std. Error | Z | Marginal Effect | Std. Error | Z |
|---|---|---|---|---|---|---|
| Intercept | 0.4999 | 0.4881 | 1.0241 | 0.1868 | 0.1934 | 0.9657 |
| PLANCON | -0.1255 | 0.0501 | -2.5021 ** | -0.0422 | 0.0168 | -2.5114 * |
| CONLEASE | -0.1530 | 0.0425 | -3.6022 *** | -0.0514 | 0.0142 | -3.6225 *** |
| ENSECURE | 0.2874 | 0.0556 | 5.1708 *** | 0.0966 | 0.0186 | 5.1802 *** |
| LINPUT | 0.3652 | 0.0591 | 6.1842 *** | 0.1227 | 0.0199 | 6.1633 *** |
| CRPQUAL | 0.0662 | 0.0478 | 1.3864 | 0.0223 | 0.0160 | 1.3872 |
| HABITAT | 0.0176 | 0.0557 | 0.3162 | 0.0059 | 0.0187 | 0.3160 |
| MARKCON | 0.0975 | 0.0573 | 1.7016 * | 0.0328 | 0.0193 | 1.6980 * |
| KNOW | -0.0807 | 0.0501 | -1.6095 | -0.0271 | 0.0169 | -1.6086 |
| LADOPT | -0.2134 | 0.0509 | -4.1908 *** | -0.0717 | 0.0171 | -4.1992 *** |
| AGE | -0.0177 | 0.0048 | -3.6865 *** | -0.0059 | 0.0016 | -3.6910 *** |
| EDUC | 0.0293 | 0.0479 | 0.6122 | 0.0099 | 0.0161 | 0.6120 |
| CONTRACT | 0.2040 | 0.1387 | 1.4713 | 0.0663 | 0.0435 | 1.5266 |
| HAYEQ | 0.4184 | 0.1229 | 3.4053 *** | 0.1448 | 0.0434 | 3.3391 *** |
| BEEF | -0.5663 | 0.1320 | -4.2910 *** | -0.1770 | 0.0377 | -4.6881 *** |
| FINCLT10 | -0.1545 | 0.1714 | -0.9019 | -0.0523 | 0.0583 | -0.8967 |
| FINC1030 | -0.2994 | 0.1733 | -1.7280 * | -0.1037 | 0.0615 | -1.6868 * |
| FINC3050 | -0.3825 | 0.2163 | -1.7678 * | -0.1381 | 0.0824 | -1.6765 * |
| LF | -360.2119 | | | | | |
| LLR(0) | 291.5391 *** | | | | | |
| Pct. Correctly Classified | 79.5510% | | | | | |
| McFadden Pseudo $R^2$ | 0.2881 | | | | | |

[a] The symbol '***' denotes significance at α=.01, '**' denotes significance at α=.05, and '*' denotes significance at α=.10.

[b] The marginal effect of a continuous variable on the probability of INTEREST=1 is calculated as $\frac{\partial \Pr(INTEREST=1)}{\partial z_k} = \phi(z'\alpha)\alpha_k$. The marginal effect of a dummy variable is calculated by holding the variables other than the dummy at their sample means and by calculating the probability that INTEREST=1 with the dummy value set at one and subtracting the probability with the dummy value set to zero.

Table 4. Estimated Tobit Model of Acres of Switchgrass Producers Would be Willing to Grow [a,b]

| Variable (N=541) | Est. Coeff. | Std. Error | Z | | Marginal Effect | Std. Error | Z | |
|---|---|---|---|---|---|---|---|---|
| Intercept | -29.9171 | 23.1943 | -1.2898 | | -19.2292 | 14.7506 | -1.3036 | |
| PRICE | 0.4951 | 0.2246 | 2.2044 | ** | 0.3183 | 0.1443 | 2.2053 | ** |
| FARMAC | 0.0185 | 0.0105 | 1.7524 | * | 0.0119 | 0.0068 | 1.7495 | * |
| IDLED | 50.9195 | 17.1992 | 2.9606 | *** | 32.7286 | 11.0563 | 2.9602 | *** |
| SOYD | 23.4277 | 19.0738 | 1.2283 | | 15.0582 | 12.2606 | 1.2282 | |
| COTTD | -50.3271 | 31.0473 | -1.6210 | | -32.3478 | 19.9676 | -1.6200 | |
| CORND | -7.2415 | 18.4622 | -0.3922 | | -4.6545 | 11.8658 | -0.3923 | |
| TOBD | -64.7300 | 30.2494 | -2.1399 | ** | -41.6053 | 19.4537 | -2.1387 | ** |
| WHED | 39.1425 | 19.4327 | 2.0143 | ** | 25.1589 | 12.5105 | 2.0110 | ** |
| SWEST | 82.8623 | 24.3791 | 3.3989 | *** | 53.2599 | 15.6990 | 3.3926 | *** |
| SWAC | -0.0005 | 0.0250 | -0.0215 | | -0.0003 | 0.0161 | -0.0215 | |
| MIDS | -7.8594 | 16.7766 | -0.4685 | | -5.0517 | 10.7857 | -0.4684 | |
| MIDSAC | 0.0712 | 0.0228 | 3.1216 | *** | 0.0458 | 0.0147 | 3.1128 | *** |
| OFIL10 | -58.8962 | 22.9557 | -2.5656 | ** | -37.8556 | 14.7707 | -2.5629 | ** |
| OFI1030 | -39.6842 | 18.0373 | -2.2001 | ** | -25.5071 | 11.5884 | -2.2011 | ** |
| OFI3050 | 2.4292 | 15.7995 | 0.1538 | | 1.5614 | 10.1552 | 0.1538 | |
| NOTILL | 23.6988 | 12.7020 | 1.8657 | * | 15.2324 | 8.1594 | 1.8669 | * |
| Sigma | 133.5952 | 4.9391 | 27.0487 | *** | | | | |
| LLF | -2615.426 | | | | | | | |
| LLR(0) | 183.708 | *** | | | | | | |

[a] The symbol '***' denotes significance at α=.01, '**' denotes significance at α=.05, and '*' denotes significance at α=.10.

[b] The marginal effect of a continuous variable on the expected value of ACREAGE is calculated as $\frac{\partial E[ACREAGE|ACREAGE>0}{\partial x_k} = \Phi\left(\frac{X_i\beta}{\sigma}\right)\beta_k$. The marginal effect of a dummy variable is calculated by holding the variables other than the dummy at their sample means and calculating the expected value of ACREAGE with the dummy value set to one and subtracting the expected value with the dummy value set to zero.