Farmer Willingness to Grow Switchgrass for Energy Production*

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Abstract

Increasing demand for the production of energy from renewable sources has fueled a search for alternatives to supplement those currently in production. One such alternative is switchgrass, a perennial grass native to North America that appears to have considerable potential as a biomass feedstock for energy production. While the properties of switchgrass as a biomass feedstock have been intensively studied, the potential market for switchgrass has received much less attention. A survey of Tennessee farmers was conducted to improve our understanding of those who might be willing to supply switchgrass to an emerging energy market. The results of this survey provide information on the willingness of Tennessee's agricultural producers to grow switchgrass as an energy crop and the acreage that these producers would be willing to convert to switchgrass production. The majority of respondents had not heard of growing switchgrass for energy production and roughly half were unsure as to whether they would be willing to grow switchgrass. For those with an opinion about whether they would grow switchgrass, a two limit Tobit model of acreage share was used to ascertain the effects of various farm and producer characteristics on the share of acreage they would be willing to convert to switchgrass.

JEL Classification: Q21, Q42

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Introduction

The production of energy from renewable resources has been a national aspiration since the 1970's. At that time, an energy crisis and the burgeoning environmental movement combined to focus, for really the first time, the Nation's attention on its dependence on fossil fuels and foreign sources of crude oil. Since then, enthusiasm for renewable energy has largely waxed and waned in tune with fluctuations in real energy prices. However, the commitment of federal and state governments to ensuring that a significant part of the Nation's energy needs is supplied by renewable sources has reached an unprecedented level. Examples of this commitment include a federal requirement that oil refiners use 7.5 billion gallons of renewable fuel each year - double the current level of ethanol production - by 2012 (Duffield and Collins, 2006) and adoption by 22 states and the District of Columbia of renewable fuel or portfolio standards requiring that electric utilities generate a specified amount of electricity from renewable sources (Pew Center, 2006). The motivation for these requirements is really a combination of a number of different factors, including: the increased competitiveness of renewable sources due to technological progress; an increasing global demand for energy; accumulating evidence of the role of emissions from the burning of fossil fuels in global climate change; and increased concern over the national security implications of importing 60 percent of the Nation's total annual consumption, or 12 billion barrels, of crude oil every year.

Biomass is the leading source of renewable energy in the United States, supplying roughly 2,865 trillion British Thermal Units (BTU's) or about 3 percent of U.S. energy consumption (USDOE, Energy Information Administration, 2005). Biomass encompasses all organic material that is available on a renewable or recurring basis, including wood and wood wastes, herbaceous plants/grasses, aquatic plants, manures and municipal wastes (USDOE, 2005). Biomass is used to generate liquid fuels, primarily in the form of either ethanol from corn or biodiesel from vegetable oils and animal fats (Eidman, 2006). Biomass is also used to generate electricity, with wood wastes, forest residues, and municipal solid wastes serving as the primary feedstocks (Duffield, 2006). However, an increasing demand for renewable energy, attributable, in part, to the federal and state mandates discussed above, has prompted a search for alternative feedstocks.

One such alternative is switchgrass (*panicum virgatum*). Switchgrass is a high yielding (about 6 to 8 tons per acre in the Southeast)[1], warm season, perennial grass that can grow to more than nine feet in height and be supported by a vigorous root system extending to depths of ten feet. As a natural component of the tall-grass prairie that covered most of the Great Plains and much of the southern and southeastern United States, switchgrass is well-adapted to grow in a large portion of the United States with low fertilizer applications and high resistance to naturally-occurring pests and diseases (Bransby, 2005). Switchgrass has been widely used in soil conservation efforts owing to its deep, extensive root system, which also allows it to tolerate poor soils, flooding and drought. Switchgrass can be planted in May through early June and be managed using no-till production practices. As a perennial, switchgrass only needs to be planted once every ten years or more, but can be harvested annually using conventional hay equipment. Harvesting can be performed in either a two harvest system or a single harvest occurring after the first frost. Switchgrass is eligible for the Conservation Reserve Program (CRP) with no payment

[1] A study in Georgia found that the average yield for the highest yielding cultivar, Alamo, across two different locations was 16.22 Mg/ha or 7.24 tons/acre (Bouton, 2002). An earlier study in Alabama found that the Alamo cultivar averaged 24.5 Mg/Ha dry matter yield or 11 tons/acre (Maposse *et al*. 1995).

reduction if harvested no more often than once every three years. As a result of these and other factors, Oak Ridge National Laboratory's Bioenergy Feedstock Development Program designated switchgrass a model biomass feedstock (McLaughlin, *et al.*, 1999).

The production of energy from switchgrass can occur in a number of different ways. Through a process of fermentation, it can be used to produce ethanol;[2] through combustion, either alone or by co-firing with coal or other fossil fuels, it can produce heat or electricity; and it can also be gasified to produce ethanol or other synthetic fuels. At this point in time, energy production from switchgrass is primarily limited to the burning of switchgrass pellets in stoves for home heating in remote areas (Burden, 2003). However, test burns are currently being conducted as part of the Chariton Valley Biomass Project to evaluate the prospects of co-firing switchgrass with coal.[3] The large-scale production of energy from switchgrass has a number of potential benefits. Producing energy from switchgrass rather than fossil fuels generates environmental benefits in the form of reduced atmospheric emissions of pollutants such as sulfur. Switchgrass also adds organic matter to soils[4], can help reduce erosion on highly erodable lands, and provides good forage and habitat for native wildlife. The large scale production of switchgrass could also promote economic growth in rural areas,[5] increase the returns to agricultural producers, and decrease farm program expenditures (de La Torre Ugarte, et al., 2003).

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[2] Some estimates suggest that switchgrass may be as much as 15 times more efficient than corn in the production of ethanol (McLaughlin and Walsh, 1998).

[3] For more information on this project, go to http://www.cvrcd.org/biomass.htm.

[4] With its extensive root system and ability to store carbon in the soil, switchgrass may be 20-30 times more effective at carbon sequestration than annual row crops (McLaughlin and Walsh, 1998).

[5] Economic analysis of switchgrass production in Iowa showed that for moderate yields of 3 tons per acre, at a price of $50 per ton, switchgrass could produce a positive impact on the regional economy (Brummer, Burras, Duffy, and Moore, 2002).

Despite these benefits, the market for switchgrass as an energy feedstock is not well developed and a better understanding of how this market might function is important for evaluating its potential for energy production. This study attempts to further our understanding of this market by analyzing the extent to which farmers would be willing to adopt switchgrass as a new crop. More specifically, by surveying Tennessee farmers, this study estimates both the probability of producers in Tennessee being willing to produce switchgrass and the share of their acreage they would be willing to convert to switchgrass production. These estimates explicitly consider the effects of cost variables, price, demographics, and farm characteristics on producer decisions on not only whether to grow switchgrass but also on the share of acreage to convert to switchgrass production. In addition, the effects of producers' views on renewable energy and switchgrass production and markets on willingness to produce and share of acres converted are also estimated.

Prior Research

Much of the analysis of the potential market for switchgrass has focused on estimating the costs of production, which have varied widely. For example, Walsh, et al. (1998) estimated that costs of production would range from $22/dry Mg ($19.96/dry ton) to $110/Mg ($99.82/dry ton), while transportation costs would range from $5/Mg ($4.54/dry ton) to $8/Mg ($7.26/dry/ton) for a 25 mile distance. More recently, Duffy and Nanhou (2002) have suggested that previous estimates are not directly applicable to commercial production as they were based either on land enrolled in the CRP, which requires minimal management techniques compared with commercial production, or on experimental plots that fail to capture the farming practices specific to a particular region. Duffy and Nanhou estimate that under a frost seeding of switchgrass on grassland with an airflow planter scenario, the total production costs at 1.5, 3, 4, and 6 tons/acre are $113.81, $70.26, $59.37, and $48.49 per ton, respectively. On a per acre basis, total yearly production costs at these various yield levels are $170.72, $210.78, $237.49, and $290.94 per acre. These costs include a $50/acre land charge for grassland. De la Torre Ugarte, et al. (2003) examined the economic impacts of bioenergy crop production across several regions of the United States, including the Appalachian region. For the Appalachian region, they used estimates of average yield, costs per acre, and costs per dry ton of 5.84 dry tons/acre, $108.21/acre, and $18.53/dry ton, respectively. Their costs did not include returns to land and management or machinery costs. Thus, the estimated costs from these studies, converted into 2005 dollars using the Index of Farm Prices Paid, ranged from $21.72 to $133.40 per ton or from $126.84 to $341.02 per acre. The Tennessee Agricultural Extension Service recently estimated costs of production for an annual yield of slightly less than six tons per acre at $255.34 per acre excluding returns to land and management (University of Tennessee Agricultural Extension Service, 2005).

There have also been efforts to analyze the likely nature of the future demand for switchgrass. For example, one study estimates that it would require about 1,600 dry tons or about 560,000 tons of switchgrass per year to supply a plant capable of producing 50 million gallons of ethanol per year (So, Brown, and Scott, 1998). Another study evaluated the economics of a biorefinery plant that would use 4,000 tons of biomass per day or 1,400,000 tons per year (Epplin, 2004). For co-firing with coal, it has been estimated that producing 35 MW of electrical power per year at a five percent co-fire rate would require 200,000 tons of switchgrass per year, or approximately 50,000 acres devoted to switchgrass production (Hipple and Duffy, 2002). Similarly, supplying the Tennessee Valley Authority's 7.7 million MWh Johnsonville coal-fired plant in Tennessee with enough switchgrass for a ten percent co-fire of one of its ten coal-fired generating units would require approximately 55,500 tons of switchgrass per year. At a yield of just under 6 tons per acre, about 85,332 acres of switchgrass would be needed to supply all ten coal-fired generating units with enough switchgrass to operate at a ten percent co-fire rate (English, Jensen, and Menard, 2002).

It should also be noted that the demand for commercial switchgrass production may not be limited to energy production. Girouard and Samson (2002) assert that warm season perennial grasses such as switchgrass have a number of positive traits suitable for applications in the pulp and paper industry. For example, perennial grasses produce more fiber per acre than hardwood trees and have the added advantage of an annual harvest. Further, warm season perennial grasses are more efficient at converting solar energy to biomass and consume less water than cool season grasses. These grasses can be pulped and it has been estimated that new farm receipts on the order of $20-$40 million annually could be realized in eastern Ontario and southwestern Quebec by adding 15 percent switchgrass pulp to the fine paper and hardwood market pulp already produced in these areas (Fox et al, 1999).

At least one study has considered the willingness of agricultural producers to participate in the large-scale production of switchgrass. Brummer, *et al*. (2002) surveyed 52 members of the agricultural community in the Chariton Valley area of Iowa about the potential benefits of, and impediments to, growing switchgrass. Among the benefits cited were that switchgrass supplied both summer forage and a spring calving milieu; it was a recommended grass for CRP land; and it promoted erosion control, soil conservation, improved water quality, and wildlife habitat. Impediments suggested by these farmers included the belief that some government programs and policies discouraged adoption of alternative crops such as switchgrass; the existence of potential time conflicts between on-farm management of switchgrass and off-farm employment; the increased complexity associated with alternative farming; the need for additional training, information and capital outlays; the lack of secure land tenure and/or acreage control for a crop with a lengthy establishment period; and concerns about the absence of secure, reliable markets (Hipple and Duffy, 2002). Taken together, all of these studies provide useful insights into the characteristics and costs of switchgrass production, as well as some issues producers are likely to consider in deciding whether to produce switchgrass. This study extends this body of research by conducting a more rigorous analysis of the factors that are likely to influence the willingness of agricultural producers to convert acreage to switchgrass using the economic modeling framework presented in the following section.

Study Methods and Data Analysis

A mail survey designed to obtain information on Tennessee farmers' willingness to grow switchgrass for energy production was conducted in March and April of 2005. A total of 15,002 surveys were sent to a statewide random sample of farmers reporting or estimated to have at least $10,000 in sales of agricultural commodities during the 2002 Census of Agriculture. This represents a majority of the 19,684 Tennessee farmers estimated to have had at least $10,000 in sales of agricultural commodities (USDA/NASS, 2002). The selection of the sample and all mailings were conducted by the Tennessee Agricultural Statistics Service. As a result, no names or addresses were available to the principle investigators and the survey was able to assert that individual responses would be confidential. The survey instrument consisted of a brief description of switchgrass and its use as an energy feedstock followed by 27 questions covering the (i) respondent's knowledge of, and interest in, switchgrass as an energy crop; (ii) the respondent's opinion on a number of topics related to switchgrass production as a biomass feedstock; (iii) characteristics of the farm operation, including types of enterprises and use of various agricultural practices; (iv) financial matters, including sources and extent of income; and (v) socio-demographic characteristics of the respondents.[6] The survey was accompanied by a cover letter explaining the purpose of the survey and a postage-paid return envelope. The initial mailing of the survey was followed one week later by a reminder postcard. A follow-up mailing to non-respondents was conducted three weeks later. This follow-up mailing included a letter emphasizing the importance of the survey, a new copy of the questionnaire, and another postage-paid return envelope.

Non-Response Analysis

Of the 15,002 mailed surveys, 3,499 were completed and returned, 282 were returned as undeliverable, 102 were returned because the addressee was no longer capable of farming, and 90 were returned by addressees for a variety of other reasons. Eliminating the surveys returned as undeliverable and those where the respondent was no longer capable of farming produces a response rate of 23.94%. While no socio-economic data for non-respondents was available, the researchers did have access to geographical information in the form of the addressee's zip code. Chi-Squared tests were used to evaluate variation in response rate between urban and rural counties and between the different regions of the state (east, middle and west). No significant variation was found in either of these tests, suggesting the absence of non-response bias across these geographies.

The survey respondents were generally representative of the United States Department of Agriculture's (USDA) statistical profile of the farming community in Tennessee (USDA/ERS,

[6] A copy of the survey instrument is available from the authors upon request.

2005). The average age of the survey respondents was 60 years (N=3,237), slightly higher than the estimated average age of all farm operators in Tennessee of 56 years. The respondents farmed 200.4 acres on average (N=3,068), while the average size of farms in Tennessee is 133 acres. The average farm debt to asset ratio for the state is 9.8 percent, while the most common debt to asset ratio among the respondents was zero, with nearly 80 percent of the respondents providing this response (N=2,941). A weighted average calculated at the category intervals for debt to asset ratio falls between 4 and 5 percent. Finally, the most common category of after-tax net farm income for respondents was $0 to $9,999, with 49.3 percent of the observations falling into this category (N=2,971), while the 2002 Census of Agriculture's estimate of average net farm income was $4,185. Therefore, while respondents appear to be generally representative of the farm population, respondents were, on average, a little older, farmed quite a few more acres, and reported a somewhat lower debt to asset ratio. Some of these differences may be due to the fact that the sample for the survey only included farms with at least $10,000 in sales.

Economic Model

The farmers considering switchgrass are assumed to maximize the expected utility of wealth, where wealth would include initial wealth, profits resulting from production of switchgrass or other crops, and profits from non-farm activities. The farmer would choose acreage to convert to switchgrass so as to maximize this expected utility. The decision modeled is then the proportion of acreage a producer would consider converting to switchgrass if switchgrass production is profitable. The proportion of acreage converted could either be zero or take on some positive value up to one. Use of the Tobit model allows estimation of the effects of explanatory variables not only upon the decision to grow switchgrass, but also upon the share of acreage to be converted. Let *SHRSWIT* be the share of acres farmed that would be converted to switchgrass, X be a matrix of explanatory variables, β be a vector of parameters, and y^* be an unobserved latent variable. Then, for the ith observation

$y^*=X_i'\beta + u_i$

$$SHRSWIT_i \begin{cases} =0 & \text{if } y^* \leq 0, \\ =y_i^* & \text{if } 0< y^*<1 \\ =1 & \text{if } y^* \geq 1 \end{cases} \tag{1}$$

where u is distributed as $N(0,\sigma^2)$. The likelihood function for the Tobit model with *SHRSWIT* having a limit at 0 and a limit at 1 can be expressed as (Maddala, 1983):

$$L = \prod_{SHRSWIT=0} \Phi\left(\frac{(0-\beta' X_i}{\sigma}\right) \prod_{0<SHRSWIT<1} (1/\sigma)\phi\left(\frac{(SHRSWIT_i - \beta' X_i)}{\sigma}\right) \prod_{SHRSWIT=1} \left[1-\Phi\left(\frac{(1-\beta' X_i}{\sigma}\right)\right] \tag{2}$$

The expected value of the share of switchgrass acreage is

$$E(SHRSWIT_i) = 0*\Phi\left(\frac{(0-\beta' X_i}{\sigma}\right) + 1*\left[1-\Phi\left(\frac{(1-\beta' X_i}{\sigma}\right)\right] + \left[\left[1-\left(\Phi\left(\frac{(0-\beta' X_i}{\sigma}\right)+\left[1-\Phi\left(\frac{(1-\beta' X_i}{\sigma}\right)\right]\right)\right]*\beta' X_i + \sigma\frac{\phi\left(\frac{(0-\beta' X_i}{\sigma}\right)-\phi\left(\frac{(1-\beta' X_i}{\sigma}\right)}{\Phi\left(\frac{(1-\beta' X_i}{\sigma}\right)-\Phi\left(\frac{(0-\beta' X_i}{\sigma}\right)}\right]. \tag{3}$$

The first term in equation 3 is the probability of a zero share multiplied by zero, while the second term is the probability of a one share multiplied by one. The third term is the probability of a share between zero and one multiplied by the expected share given that it lies between these two bounds. This general framework has been used in modeling acreage decisions, including technology adoption, such as biotechnology, or other cropping decisions (Adesina and Zinna, 1993; Baidu-Forson, 1999; Fernandez-Cornejo *et al.* 2001; Gould *et al.* 1989; Kristjanson *et al*. 2005; Norris and Batie, 1987; Rajasekharan and Veeraputhran, 2002; Ransom, *et al*. 2003).

The general list of variables hypothesized to influence the share of acreage a producer would be willing to convert to switchgrass is presented in **Table 1**, along with a description and mean value for these variables. These means are calculated only for those observations that have all of the data needed by the econometric model. The *a priori* hypothesized effects of these variables on share of acreage that would be converted are summarized in **Table 2**. The choice of variables to include in the model and the hypothesized effects of these variables were based both on prior analysis of producer opinions on switchgrass (Brummer, *et al*. 2002) and on the more general literature on crop and technology adoption. Particular attention was paid to studies of factors influencing the adoption of conservation practices given switchgrass' potential for reducing erosion problems. These variables were drawn from each of the different sections of the survey – characteristics of the farm operation, financial matters, respondent demographics, and knowledge of, and opinions on, matters related to switchgrass production – and grouped accordingly.

The variables included to capture the effects of farm characteristics on willingness to produce switchgrass are: the total number of acres farmed, whether the respondent leased any of those acres, whether the respondent believed that his or her farm had an erosion problem, whether the farm had any acreage planted in a grass and enrolled in the CRP, whether the respondent employed no-till production practices, the number of different crops a respondent grew, whether the respondent had livestock, hay equipment, or idled acreage, whether the respondent leases out land for hunting, and whether the farm was located in an urban county or a county with a coal-fired power plant. Farm size or total acres farmed is expected to have a positive influence on the willingness to grow switchgrass based on other analyses of crop or technology adoption (Fernandez-Cornejo *et al*. 2001; Gould *et al*. 1989; Nkonya, *et al*. 1997; Norris and Batie, 1987; Rajasekharan and Veeraputhran, 2002). Leasing acres is expected to have a negative influence on willingness to convert acreage to switchgrass as insecure land tenure may reduce the expected value of growing a perennial such as switchgrass (Featherstone and Goodwin, 1993; Lynne *et al*. 1988; Norris and Batie, 1987). The perception that a farm has an erosion problem is expected to have a positive influence on willingness to grow switchgrass (Ervin and Ervin, 1982; Norris and Batie, 1987). Having grass land enrolled in the CRP, and the use of no-till practices are also hypothesized to positively affect a producer's willingness to grow switchgrass because they evidence a willingness to adopt conservation-minded practices.

The effect of growing a particular crop cannot, in general, be hypothesized *a priori,* although Norris and Batie (1987) found that tobacco acreage had a negative effect on conservation expenditures, but not acres under conservation tillage. Growing hay or having hay equipment is expected to have a positive influence on willingness to grow because hay equipment and practices are readily adaptable to switchgrass. Having livestock, which might compete with the conversion of hay or pasture land to switchgrass, is hypothesized to have a negative influence. Growing a greater variety of crops is believed to signal a producer's desire to diversify or willingness to try new crops and is therefore expected to have a positive influence on willingness to grow switchgrass (Kristjanson *et al*. 2005). Location in an urban area could have a positive influence on willingness to grow as producers located near urban centers might be eager to try a less input intensive crop. Location in a county with a coal-fired power plant is expected to have a positive influence on willingness to grow due to as these farms may possess greater access to a potential market (Akinola and Young, 1985; Ransom *et al*. 2003).

The variables related to financial matters included net farm income per acre, whether respondent was debt-free, percent of household net income from off-farm sources, farm ownership, and whether the respondent was a hobby farmer. While one might expect that greater farm income would increase a producer's willingness or ability to try a new crop (Gould *et al.*, 1989), higher net returns per acre on existing crops would imply a greater opportunity cost of converting acreage out of those crops (Norris and Batie, 1987). Being debt free could signal an unwillingness to assume debt to try a new crop and, thus, a reluctance to convert acreage to switchgrass.[7] While a household's off-farm income could provide the funding for new crop adoption, it could also represent a competitor for the investment of time needed for growing a new crop. On the other hand, greater off-farm employment could positively influence the decision to grow a new crop, if the new crop is perceived to be less time-consuming than existing crops. The evidence from the literature on the effect of off-farm income on crop or technology adoption is mixed (Fernandez-Cornejo *et al.* 2001; Gould *et al.* 1989; Norris and Batie, 1987; Rajasekharan and Veeraputhran, 2002; Ransom, *et al*. 2003). Full ownership should imply greater control over cropping decisions and thus an increased likelihood of adoption, while switchgrass' in-field characteristics might appeal to hobby farmers who might place a high value on the non-monetary benefits associated with farm ownership.

Since switchgrass can provide wildlife habitat and be beneficial to bird hunting, respondents who issue hunting licenses or belong to a hunting or environmental organization may be more likely to be willing to grow switchgrass. Membership in a grower or commodity organization likely evidences commitment to a current crop and would negatively influence an individual's likelihood of growing switchgrass. The effect of membership in Farm Bureau is not

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[7] See Featherstone and Goodwin, 1993, Gould *et al*. 1989, Lynne *et al*. 1988, and Norris and Batie, 1987, for alternative treatments of farm debt.

hypothesized *a priori*. Producers who are older may be less inclined to invest the resources necessary to grow a new crop (Akinola and Young, 1985; Featherstone and Goodwin, 1993; Gould *et al.* 1989; Norris and Batie, 1987; Rajasekharan and Veeraputhran, 2002), while less educated respondents may not be as open to acquiring the information necessary to grow switchgrass (Ervin and Ervin, 1982; Fenandez-Cornejo *et al*. 2001; Nkonya, *et al*. 1997).

Farmers who had less concerns about the viability of markets, time conflicts with planting and harvesting, and potential CRP limits on harvesting intervals are expected to be more willing to grow switchgrass. Those who had more positive views about erosion control benefits, importance of biomass to reduce atmospheric emissions, and provision of wildlife habitat are postulated to be more willing to grow switchgrass. Those who believed they would need technical assistance or government payments are hypothesized to be less willing to grow switchgrass. Those who believed switchgrass was less risky than other crops or who were willing to use long-term contracts are expected to be more willing to grow switchgrass.

Table 1. Variable Names, Descriptions, and Means

Variable	**Description**	**Mean (N=728)**
Share of Acres Farmed Would Convert to Switchgrass	Share of total acres farmed that would convert to switchgrass, range 0 to 1	0.23912
Prior Knowledge About Switchgrass	1 if had prior knowledge, 0 otherwise	0.27747
Net Farm Income Per Acre	Net farm income level per acre in 2004 after taxes. Mid-point of interval/acres farmed (Mid-points \$0, \$5,000, \$12,500, \$20,000, \$30,000, \$42,500, \$62,500, \$87,500, \$125,000, \$150,000)[a]	238.50199
Acres Farmed	Total number of acres farmed	199.63352
Debt Free	1 if debt free, 0 otherwise	0.69643
Percent Off Farm Income	Percent of 2004 household net income from off-farm sources	52.74451
Lease Some Land	1 if lease some land, 0 otherwise	0.47115
Hobby	1 if net farm income < \$10,000 and off farm income > 50%, 0 otherwise	0.23626
Full Owner	1 if full owner, 0 otherwise	0.77060
Erosion Problem	1 if have erosion problem, 0 otherwise	0.56181
Have CRP Grass Acres	1 if have, 0 otherwise	0.05632
Use No Till	1 if use, 0 otherwise	0.47390

Table 1. Continued.

Variable	Description	Mean (N=728)
Grow Hay	1 if grow, 0 otherwise	0.81181
Have Hay Equipment	1 if have, 0 otherwise	0.73489
Grow Soybeans	1 if grow, 0 otherwise	0.10440
Grow Cotton	1 if grow, 0 otherwise	0.01923
Grow Corn	1 if grow, 0 otherwise	0.14973
Have Idled Acreage	1 if have, 0 otherwise	0.02885
Grow Tobacco	1 if grow, 0 otherwise	0.13324
Number of Crops Grown	number of crops	1.61264
Have Livestock	1 if have, 0 otherwise	0.84753
Issue Hunting Leases	1 if issue, 0 otherwise	0.10302
Age	age of farmer in years	57.40659
Education Level	1=some high school or less, 2=high school graduate, 3=some college, 4=college graduate, 5=post graduate	3.04670
Member of Environmental Organization	1 if member, 0 otherwise	0.05632
Member of Hunting Organization	1 if member, 0 otherwise	0.12363
Member of Grower/Commodity Organization	1 if member, 0 otherwise	0.08654
Member of Farm Bureau	1 if member, 0 otherwise	0.76923
Located in Urban County	1 if located in county in 1,000,000 or more metropolitan area	0.25687
Located in County with Coal-Fired Power Plant	1 if located in county with coal-Fired power plant, 0 otherwise	0.08654
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.51511
Planting period for switchgrass will conflict with planting period for my other crops	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	3.29670
Harvesting period for switchgrass will conflict with harvesting period for my other crops	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	3.28022
Switchgrass can help control erosion on my land	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.46841
I am concerned that markets for switchgrass are not sufficiently developed	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.14698
Production risk for switchgrass is lower than other crops or products I currently produce	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.82143
Switchgrass use in producing electricity or fuels should be subsidized by the government	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.59478
I would consider signing long-term contracts to grow switchgrass for energy	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.65247
I would need technical assistance regarding growing and harvesting switchgrass	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.19780
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.07967
I would like to provide more habitat for native wildlife species on my own land	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.35027
I would need government payments in order to produce switchgrass	Rating of 1=strongly agree, 2=agree, 3=no opinion, 4=disagree, 5=strongly disagree	2.60165

[a] 2005 farm income intervals on the survey were 1=negative, 2=$0-$9,999, 3=$10,000-$14,999, 4=$15,000-$24,999, 5=$25,000-$34,999, 6=$35,000-$49,999, 7=$50,000-$74,999, 8=$75,000-$99,999, 9=$75,000-$99,999, 10=$100,000-149,999, 11=greater than or equal to $150,000.

Table 2. Hypothesized Effects on Share of Acres Converted to Switchgrass

Variable	Hypothesized Effect on Share of Acres Converted
Acres Farmed	+
Lease Some Land	-
Erosion Problem	+
Have CRP Grass Acres	+
Use No Till	+
Number of Crops Grown	-
Grow Hay	+
Have Hay Equipment	+
Grow Soybeans	?
Grow Cotton	?
Grow Corn	?
Grow Tobacco	+
Have Idled Acreage	+
Have Livestock	-
Issue Hunting Leases	+
Located in Urban County	+
Located in County with Coal-Fired Power Plant	+
Full Owner	+
Debt Free	-
Net Farm Income Per Acre	-
Hobby	+
Percent Off Farm Income	?
Age	-
Education Level	+
Member of Environmental Organization	+
Member of Hunting Organization	+
Member of Grower/Commodity Organization	-
Member of Farm Bureau	?
Prior Knowledge About Switchgrass	+
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	-
Planting period for switchgrass will conflict with planting period for my other crops	-
Harvesting period for switchgrass will conflict with harvesting period for my other crops	-
Switchgrass can help control erosion on my land	+
I am concerned that markets for switchgrass are not sufficiently developed	+
Production risk for switchgrass is lower than other crops or products I currently produce	+

Table 2. Continued.

Variable	Hypothesized Effect on Share of Acres Converted
Switchgrass use in producing electricity or fuels should be subsidized by the government	+
I would consider signing long-term contracts to grow switchgrass for energy	+
I would need technical assistance regarding growing and harvesting switchgrass	-
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions	+
I would like to provide more habitat for native wildlife species on my own land	+
I would need government payments in order to produce switchgrass	-

Results

Stated Knowledge of and Interest in Growing Switchgrass as an Energy Crop

Producers were first asked if they had ever heard of growing switchgrass as a crop to be used in energy production. Of those responding, 689, or 20.8 percent, had previously heard of switchgrass being grown for this reason (N=3,312). Next, the producers were asked whether they would be interested in growing switchgrass if it were profitable to do so. Of the 3,244 respondents to this question, 23.7 percent stated that they would not be interested, 29.6 percent that they would be interested, and 46.7 percent that they were unsure or did not know. As shown in **Table 3**, there was a significant association between prior knowledge of switchgrass production for energy and interest in growing switchgrass ($X^2 = 44.6$ with 2 df). Among those with prior knowledge of switchgrass as an energy crop, nearly 39 percent were interested in growing it, while only 27 percent of those who did not know about switchgrass were interested in growing it (N=3,229).

Table 3. Stated Knowledge About and Interest in Growing Switchgrass.

	Have Heard of Growing Switchgrass for Energy Production	
Interested in Growing	No	Yes
No	23.4	24.8
Don't Know	49.3	36.3
Yes	27.2	38.9

Acreage to be Planted in Switchgrass

Producers who stated they were interested in growing switchgrass were then asked how many acres they would be willing to convert to switchgrass and what crops they would convert. Descriptive statistics for the acreage question are presented in **Table 4**. While the mean acres that would be converted (among those stating some positive acreage conversion) was 67.3, the median was 48.5 acres. The total acreage that would be converted among the 684 respondents willing to grow switchgrass was 46,033 acres.

Table 4. Acres to be Converted.

Statistic	Acres to be Converted
Mean	67.3
Standard Deviation	87.2
Median	48.5
N	684

Views on Switchgrass Production and Markets

Producers who expressed an opinion on whether they would be willing to grow switchgrass were then asked to indicate the extent to which they agreed with a number of statements regarding the production and marketing of switchgrass. A summary of their responses is provided in **Table 5**. Strong agreement with the statement was rated as '1' while strong disagreement was rated a '5'. The letters in the third column denote means which could not be found to be significantly different from each other at the 95 percent confidence level using t-tests. As can be seen in **Table 5**, the statement that producers agreed with most was about production of more of the Nation's energy from biomass as an effective way to control atmospheric emissions. The statements that they were in the next highest level of agreement with were about the need for technical assistance and concern over the absence of markets for switchgrass. The statements they agreed with least were that growing switchgrass would conflict with planting or harvesting times of their current crops.

The mean ratings for the level of agreement between those who were willing to grow switchgrass and those who were not are contrasted in the fourth and fifth columns of **Table 5**. For each of the statements, there was a significant difference in the mean ratings at the 95 percent confidence level. Compared with those not interested in growing switchgrass, those interested in switchgrass were in more agreement with the statements that: switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive; switchgrass can help control erosion on their land; the absence of sufficiently developed markets was a concern; production risk for switchgrass is lower than other crops they were currently producing; switchgrass use should be subsidized by the government; they would consider signing long-term contracts; they would need technical assistance; producing more of our nation's energy from biomass was an effective way to control atmospheric emissions; they would like to provide more habitat for native wildlife species on their own land; and they would need government payments in order to produce switchgrass. Those willing to grow switchgrass agreed less with statements that the planting period for switchgrass will conflict with the planting period for other crops and that the harvesting period for switchgrass will conflict with harvesting period for their other crops.

Table 5. Producer Opinions About Switchgrass Production and Markets.[a,b]

Statement	Overall Means (1=strongly agree…5=strongly disagree) (N=1259)		Mean Rating Among Those Who Would Not Grow (N=428)	Mean Rating Among Those Who Would Grow (N=831)	
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	2.5385	a	2.7874	2.4103	*
Planting period for switchgrass will conflict with planting period for my other crops	3.3082	b	2.8949	3.5211	*
Harvesting period for switchgrass will conflict with harvesting period for my other crops	3.3058	b	2.9112	3.5090	*
Switchgrass can help control erosion on my land	2.4790	a	2.8855	2.2696	*
I am concerned that markets for switchgrass are not sufficiently developed	2.1946	c	2.5771	1.9976	*
Production risk for switchgrass is lower than other crops or products I currently produce	2.8388		2.9463	2.7834	*
Switchgrass use in producing electricity or fuels should be subsidized by the government	2.6283	d	2.9136	2.4813	*
I would consider signing long-term contracts to grow switchgrass for energy	2.6450	d	3.4042	2.2539	*
I would need technical assistance regarding growing and harvesting switchgrass	2.1906	c	2.6729	1.9422	*
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions	2.0882		2.5981	1.8255	*
I would like to provide more habitat for native wildlife species on my own land	2.3852		2.8762	2.1324	*
I would need government payments in order to produce switchgrass	2.5997	a,d	2.8668	2.4621	*

[a] Like letters indicate means for which the null hypothesis that the means are equal could not be rejected at the 95 percent confidence level.
[b] *=significant difference at the 95 percent confidence level in mean rating by those who would grow switchgrass compared with those who would not.

Acreage Share Conversion Decision Model

The results from the estimated two limit Tobit model of share of acreage conversion to switchgrass are shown in **Table 6.** As indicated by the log-likelihood ratio comparing the model with an intercept only model, the model was significant. A total of 728 observations were used in the Tobit model. The model correctly classified 84.62 percent of the observations with respect to whether the farmer would convert some of their acres farmed to switchgrass. The model correctly classified 94.78 percent of the observations with respect to whether the farmer would convert all of their acres farmed to switchgrass. The McFadden's Pseudo R^2 was .381075.

The coefficients on the following farm and farmer characteristics were significantly different from zero and carried a negative sign: net farm income per acre, acres farmed, lease some land, have idled acreage, number of crops grown, have livestock, age, and membership in a grower/commodity organization. It was hypothesized that if net farm income per acre represents the opportunity cost of converting acreage to switchgrass out of current uses, the higher the current net farm income per acre, the lower the share converted. The results support this hypothesis. While some previous studies have suggested a positive relationship between share of technology adoption in crops and size of farm, the results from this model show a negative effect. This result could reflect the nature of switchgrass compared with the crops or technologies evaluated in other adoption studies. For example, smaller farms may benefit more from switchgrass' ability to grow on marginal lands with relatively low input levels.than large farms. Leasing of land would potentially limit management decisions on acreage allocations, therefore the negative sign was anticipated. The negative sign on idled acreage could reflect that producers with idled land are already not fully utilizing their land and therefore would be less willing to devote resources to growing a new crop. Contrary to the positive sign hypothesized, the coefficient on crop diversification was negative. The negative sign on crop diversification suggests that for farmers who keep a diversified crop portfolio, the share they would be willing to convert to switchgrass would be less. As postulated, the negative sign on having livestock could reflect associated pasture and demands which would decrease the share the farmers would allocate to switchgrass. The negative sign on the coefficient on age was expected and indicates younger farmers' willingness to convert acreage into new crops. This finding is consistent with findings from past studies with regard to the effect of age on technology adoption. The negative sign on membership in a grower/commodity organization could reflect that membership in a particular type of commodity organization signals commitment to production of a particular commodity.

The coefficients on the following farm and farmer characteristics were significant and positive: percent of income from off farm sources, use of no till, have hay equipment, grow soybeans, education level, and location in a county with a coal-fired power plant. While the sign on the coefficient for off farm income was not hypothesized *a priori*, it could suggest that off farm income might be viewed as a way to offset income risks from trying a new crop. Use of no till practices reflects a willingness to try environmentally friendly technologies, therefore producers who are willing to use no till might be more willing to grow a new crop with environmental benefits. Producers who have hay equipment already have equipment needed to harvest switchgrass, therefore the positive sign was anticipated. The positive sign on whether the farmer grew soybeans could indicate two things. First, soybean growers may have more positive views on energy crop development because of the emerging development of biodiesel. Second, soybean market conditions were not favorable in the time period just prior to the survey (average 2003/2004 prices were $7.34 per bushel, while average 2004/2005 prices were $5.74 per bushel), hence soybean producers might have been more interested in alternative crops. Those with higher education levels were willing to convert greater shares to switchgrass. A positive sign on education is consistent with prior studies on technology adoption. The positive sign on location in a county with a coal-fired plant could signal the role of farmers' views about end user proximity in their acreage allocation.

The estimated coefficients on some of the farm and farmer characteristics were not significant. These included coefficients on prior knowledge about switchgrass, being debt free, hobby/part-time status, full ownership, have an erosion problem, have CRP grass acres, grow hay, grow cotton, grow corn, grow tobacco, issue hunting leases, and membership in environmental, hunting, or Farm Bureau organizations, and location in an urban county.

The estimated coefficients on several of the variables representing the farmers' views on switchgrass and energy markets were significant. Those who were more concerned about harvesting limits to retain CRP payments and about market development would convert a larger share. Also, those who were in more agreement that they would consider signing long-term contracts, would need technical assistance, and would like to provide more habitat for native wildlife on their land would convert larger acreage shares to switchgrass. However, those who were more concerned about the planting period for switchgrass conflicting with planting period for other crops would convert a lower share. The coefficients on the opinions regarding potential harvesting conflicts, use of switchgrass to control erosion, production risk relative to other crops, potential subsidization of switchgrass use, use of biomass in energy production to control atmospheric emissions, and need for government payments to produce switchgrass were not significantly different from zero.

Table 6. Two Limit Tobit Model of Share of Acres To Be Converted to Switchgrass.

Variable	Estimated Coefficient	Standard Error	T-Ratio	Sign-ificance Level	
Intercept	1.09167	0.15783	6.91667	0.00000	***
Prior Knowledge About Switchgrass	0.01619	0.03293	0.49159	0.62301	
Net Farm Income Per Acre	-0.00005	0.00003	-1.84142	0.06556	**
Acres Farmed	-0.00037	0.00007	-5.14473	0.00000	***
Debt Free	-0.01088	0.03272	-0.33248	0.73953	
Percent Off Farm Income	0.00054	0.00041	1.33635	0.18144	*
Lease Some Land	-0.07659	0.03300	-2.32133	0.02027	***
Hobby	0.06277	0.05286	1.18729	0.23511	
Full Owner	-0.00045	0.03573	-0.01265	0.98990	
Erosion Problem	0.03093	0.03147	0.98288	0.32567	
Have CRP Grass Acres	-0.02065	0.06342	-0.32553	0.74478	
Use No Till	0.07902	0.03120	2.53252	0.01132	***
Grow Hay	0.03907	0.04841	0.80705	0.41964	
Have Hay Equipment	0.05704	0.03875	1.47189	0.14105	*
Grow Soybeans	0.13393	0.05696	2.35133	0.01871	***
Grow Cotton	0.06474	0.10714	0.60426	0.54567	
Grow Corn	0.06676	0.05534	1.20632	0.22769	
Have Idled Acreage	-0.12641	0.08920	-1.41717	0.15643	*
Grow Tobacco	-0.01702	0.05065	-0.33611	0.73679	
Number of Crops Grown	-0.03326	0.02519	-1.32031	0.18673	*
Have Livestock	-0.12201	0.04557	-2.67759	0.00742	***
Issue Hunting Leases	-0.05207	0.04812	-1.08226	0.27914	
Age	-0.00400	0.00139	-2.88695	0.00389	***
Education Level	0.04543	0.01259	3.60894	0.00031	***
Member of Environmental Organization	0.06574	0.06154	1.06823	0.28542	
Member of Hunting Organization	0.05530	0.04389	1.25975	0.20776	
Member of Grower/Commodity Organization	-0.07203	0.05266	-1.36769	0.17141	*
Member of Farm Bureau	0.03461	0.03534	0.97943	0.32737	
Located in Urban County	0.01426	0.03579	0.39842	0.69032	
Located in County with Coal-Fired Power Plant	0.06967	0.05168	1.34804	0.17765	*
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	-0.02676	0.01572	-1.70249	0.08866	**
Planting period for switchgrass will conflict with planting period for my other crops	0.04681	0.02828	1.65548	0.09783	**
Harvesting period for switchgrass will conflict with harvesting period for my other crops	0.01195	0.02836	0.42133	0.67352	
Switchgrass can help control erosion on my land	-0.00935	0.01978	-0.47265	0.63647	
I am concerned that markets for switchgrass are not sufficiently developed	-0.07058	0.01949	-3.62141	0.00029	***

Table 6. Continued.

Variable	Estimated Coefficient	Standard Error	T-Ratio	Sign-ificance Level	
Production risk for switchgrass is lower than other crops or products I currently produce	-0.00146	0.02102	-0.06925	0.94480	
Switchgrass use in producing electricity or fuels should be subsidized by the government	0.01478	0.01765	0.83739	0.40237	
I would consider signing long-term contracts to grow switchgrass for energy	-0.18889	0.01915	-9.86392	0.00000	***
I would need technical assistance regarding growing and harvesting switchgrass	-0.04467	0.02150	-2.07741	0.03776	**
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions	-0.01338	0.02270	-0.58935	0.55563	
I would like to provide more habitat for native wildlife species on my own land	-0.06580	0.01785	-3.68669	0.00023	***
I would need government payments in order to produce switchgrass	-0.00986	0.01846	-0.53391	0.59340	
Sigma	0.34040	0.01261	27.00250	0.00000	***
Log Likelihood Function	-330.0727				
LLR Test Against Intercept Only (41 df)	406.455				
Number of Observations	728				
Percent Correctly Classified for Conversion of Some Acres	84.62%				
Percent of Classified for Conversion of All Acres	94.78%				
McFadden's Pseudo R^2	0.381075				

*** indicates significant at α=.05, ** indicates significant at α =.10, * indicates significant at α =.20.

The marginal effects, their estimated standard errors, and t-ratios for the continuous variables are presented in Table 7.[8] The marginal effects are presented for variables for which the estimated coefficients in the Tobit model were significant. For each additional acre farmed,

[8] The marginal effect of a variable x_k on SHRSWIT is calculated as:

$$\frac{\partial E(SHRSWIT \mid x)}{\partial x_k} = E(SHRSWIT \mid x, 0 < SHRSWIT^* < 1) * \left[\frac{\partial\{\Phi[(1-\beta' x)/\sigma] - \Phi[-\beta' x/\sigma]\}}{\partial x_k}\right]$$

$$+ \{\Phi[(1-\beta' x)/\sigma] - \Phi[-\beta' x/\sigma]\} * \frac{\partial E(SHRSWIT \mid x, 0 < SHRSWIT^* < 1)}{\partial x_k} + \frac{\partial \Phi[-((1-\beta' x)/\sigma)]}{\partial x_k}.$$

the share of acreage converted would decline by .00023 and for each additional crop grown, the share converted would decline by .02077. When the marginal effects are compared across several of the opinions variables, interestingly, agreement/disagreement with the statement that the producer would consider signing long term contracts had the largest effect on share of acreage, perhaps signaling the need for contract market arrangements in developing switchgrass markets.

Table 7. Marginal Effects of Continuous Variables on Share of Acreage Converted.

Variable	Marginal Effect	Standard Error	T-Ratio	Significance Level	
Farm income per acre	-0.00003	0.00002	-1.85911	0.0630	**
Acres farmed	-0.00023	0.00005	-5.10412	0.0000	***
Number of crops grown	-0.02077	0.01574	-1.31936	0.1870	*
Age	-0.00250	0.00086	-2.89455	0.0038	***
Education	0.02838	0.00784	3.618981	0.0003	***
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	-0.01671	0.00981	-1.70362	0.0885	**
Planting period for switchgrass will conflict with planting period for my other crops	0.02924	0.01763	1.658048	0.0973	**
I am concerned that markets for switchgrass are not sufficiently developed	-0.04408	0.01214	-3.6321	0.0003	***
I would consider signing long-term contracts to grow switchgrass for energy	-0.11797	0.01179	-10.0058	0.0000	***
I would need technical assistance regarding growing and harvesting switchgrass	-0.02790	0.01339	-2.08316	0.0372	***
I would like to provide more habitat for native wildlife species on my own land	-0.04109	0.01110	-3.7018	0.0002	***

*** indicates significant at α=.05, ** indicates significant at α =.10, * indicates significant at α =.20.

For the significant discrete variables, the expected value of acreage share was calculated, for example, with the variable held at zero and then held at one with all other variables held at their means using the formula in equation 3. The changes in the expected acreage share were then calculated. These results are presented in Table 8. The largest positive change in expected share was for growing soybeans, while the largest negative change was for having livestock.

Table 8. Changes in Expected Value of Acreage Share Given Changes in Discrete Variables.

Variable	Expected Acreage Share at Variable=0	Expected Acreage Share at Variable=1	Change in Expected Acreage Share
Lease Some Land	0.22191	0.17428	-0.04763
Use No Till	0.17606	0.22555	0.04949
Have Hay Equipment	0.17346	0.20825	0.03479
Grow Soybeans	0.19006	0.28082	0.09076
Have Idled Acreage	0.20097	0.13041	-0.07056
Have Livestock	0.26869	0.18725	-0.08144
Member of Grower/Commodity Organization	0.20260	0.15997	-0.04263
Located in County with Coal-Fired Power Plant	0.19494	0.24053	0.04559

Conclusions

The results from this study suggest that many farmers, at the time of the survey, were still not familiar with switchgrass. However, slightly less than 30 percent would be willing to grow switchgrass if it were profitable. Farmers felt positively about the importance of increasing biomass use in energy production to help control emissions. However, they were concerned that they would need technical assistance and that markets are not yet sufficiently developed. Farmers did not feel strongly that planting and harvesting of switchgrass would conflict with their current crops' planting and harvesting periods.

Farmers with higher net farm incomes per acre were willing to convert smaller shares of their farmed acres to switchgrass, reflecting the opportunity cost of converting land out of its current use. Those with higher off farm incomes were willing to convert more acreage. Unlike some prior technology adoption studies, farm size had a negative influence on the share of acres that would be converted. Interestingly, while erosion issues did not appear to influence share, desire to provide wildlife habitat did. Views about on-farm issues, such as market development, use of contracts, and potential harvest limitations under CRP influenced acreage share. However, broader national policy issues, such as the role in reducing atmospheric emissions, need for subsidization of use, and government payments to grow switchgrass did not significantly influence acreage conversion.

While switchgrass is not a new crop, its commercialization for energy use is relatively new and markets are still under development. This study provides information regarding concerns and opinions producers may have and the role these opinions may have on a producer's willingness to grow switchgrass. It also highlights the various farm characteristics and demographics which may influence both the willingness of producers to grow switchgrass and amount of acreage that they would be willing to convert to switchgrass production. Future research should examine timing of adoption and the analysis should also be expanded to a broader study region to include likely growing areas throughout the Southeast.

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