

To the Graduate Council:

I am submitting herewith a thesis written by Pamela C. Ellis entitled "Evaluation of Socioeconomic Characteristics of Farmers Who Choose to Adopt a New Type of Crop and Factors that Influence the Decision to Adopt Switchgrass for Energy Production." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Burton C English
Major Professor

We have read this thesis
and recommend its acceptance:

Kimberly Jensen

Christopher Clark

Accepted for the Council:

Linda Painter
Interim Dean of the Graduate School

(Original signatures are on file with official student records.)

**EVALUATION OF SOCIOECONOMIC CHARACTERISTICS OF
FARMERS WHO CHOOSE TO ADOPT A NEW TYPE OF CROP
AND
FACTORS THAT INFLUENCE THE DECISION TO ADOPT
SWITCHGRASS FOR ENERGY PRODUCTION**

A Thesis

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Pamela C. Ellis

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DEDICATION

This thesis is dedicated to my grandmother

Myrnie S. Ponder

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ABSTRACT

Evaluating farmers' perceptions and obtaining feedback about the adoption of a new crop is necessary for improving the efficiency of research, technology exchange, and information flow to policymakers. New technology has created new uses for non-traditional crops (such as switchgrass) as a sustainable source of energy. With new technology utilizing non-traditional crop uses, it is important to discern and understand the determinants of farmers' behavior and attitudes toward new crop adoption rather than new technology adoption. Farmers must analyze financial and social costs and benefits of new crops, farming practices, and economic activities. Better understanding of the factors farmers consider when evaluating land use change, production activities on the farm, and resource allocation will help in developing and implementing guidelines for recruiting switchgrass growers and promoting long-term producer participation in Tennessee.

Switchgrass utilization is an emerging market currently in the research and demonstration project stage. Most switchgrass research has been centered in the prairie states of the Midwestern United States and the prairie provinces of Canada. Switchgrass is a valuable soil-protection cover-crop. Switchgrass production can benefit farmers, taxpayers, industrial-fiber producers, energy producers, and consumers of energy.

Because the market for switchgrass is not well developed, information regarding producer's attitudes toward switchgrass markets, net returns required to produce switchgrass, and acreage that might be converted to switchgrass is needed. The purpose of this study is to assess the producer's views on switchgrass markets, their willingness to

produce switchgrass, and the acreage amount and type of agricultural production that might be converted.

In this study a survey was conducted to obtain information about Tennessee farmers' views on switchgrass for energy production. A logit model was then used to show what characteristics of the farm and farmer have the highest effect on adoption rates of switchgrass. Using the estimated logit model, an analysis was done to predict the likelihood of adoption of switchgrass from survey respondents who did not know if they would be interested in adopting switchgrass.

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Part 1: Introduction

Introduction

As modern agriculture developed, the production of crops became much more mechanized and input intensive. As technology and genetic manipulation through plant breeding and biotechnology increased, specialization occurred. As a result, there has been an increasing emphasis on fewer and fewer commodity crops across the country. In many regions farmers are reliant on just one or two crops for their income. Nearly 80% of the nation's annual row crop acreage is planted to wheat, corn, and soybeans. As a result of this concentration, many growers have few alternatives, and low prices on major commodities have had disastrous economic effects (Joliffe, 1997). The focus has been on increasing yields and decreasing the production costs of traditional crops. Over the last four decades, low prices for major commodities, punctuated by brief periods of prosperity, have reestablished concerns about profitable crop alternatives (Joliffe, 1997).

The continued strength of the environmental movement has spurred interest in a more sustainable and diversified agriculture while consumer demand for new foods and products has increased as a result of changing demography and health concerns (Janick et al, 1996). Throughout history, people have faced the challenge of balancing food production with protection of the environment. More recently, interest in sustainability has risen in response to environmental crises and health hazards. A sustainable agriculture is generally regarded as an alternative to modern industrialized or conventional agriculture which is described as highly specialized and capital intensive, heavily dependent upon synthetic chemicals and other off-farm inputs (Schaller, 1993). As it pertains to agriculture, sustainable describes farming systems that are "capable of

maintaining their productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound” (Ikerd, 1990). The profitability of sustainable versus conventional farming is often the most contentious issue encountered when the subject of sustainability is discussed (National Campaign for Sustainable Agriculture).

Biomass

Biomass is a renewable energy resource. It can be derived from the carbonaceous waste of various human and natural activities. Derived from numerous sources, including by-products from the timber industry, it can also consist of agricultural crops and raw material from the forest, as well as major parts of household waste and wood.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels or converted to transportation fuel through gasification, pyrolysis, or fermentation. Currently, biomass is an important source of energy and the fourth most important fuel worldwide after coal, oil and natural gas (US Department of Energy).

Many farmers already produce biomass energy by growing corn to make ethanol. But biomass energy comes in many forms. Virtually all plants and organic wastes can be used to produce heat, power, or fuel. Biomass energy has the potential to supply a significant portion of America's energy needs, while revitalizing rural economies, increasing energy independence, and reducing pollution. Farmers would gain a valuable

new outlet for their products (De La Torre Ugarte et al, 2003; English et al, 2002). Rural communities could become entirely self-sufficient when it comes to energy, using locally grown crops and residues to fuel cars and tractors and to heat and power homes and buildings (Union of Concerned Scientists, 2005).

Crops grown for energy could be produced in large quantities, just as food crops are. While corn is currently the most widely used energy crop, native trees and grasses are likely to become the most popular in the future. These perennial crops require less maintenance and fewer inputs than do annual row crops, so they are cheaper and more sustainable to produce.

Switchgrass

Switchgrass is a potential feedstock source for producing bioenergy. Switchgrass is a perennial grass that is native to North America and can be managed using common agricultural practices. Producing switchgrass generates fewer atmospheric emissions, especially sulfur. Switchgrass also adds organic matter to soils and can help reduce erosion on highly erodible lands. Furthermore, switchgrass can provide valuable habitat for wildlife (McLaughlin, et al., 1999).

Switchgrass production can benefit farmers, taxpayers, industrial-fiber producers, energy producers and consumers of energy. Bioenergy can be produced by co-firing switchgrass with coal to produce electricity in existing power plants and offers a near term energy production alternative. Eventually using switchgrass as a feedstock in bio-reactors that produce bio-based fuels or industrially important chemicals has tremendous potential (Burden, 2003).

There are several environmental benefits to switchgrass production for biomass. It can be established over a variety of landscapes and maintained as a renewable resource. With respect to energy production, switchgrass as a crop sequesters carbon, therefore reducing atmospheric carbon-dioxide content.

The use of switchgrass for energy production is still in the experimental stages and as a result the market for switchgrass is not developed. Assessing the feasibility of switchgrass production for energy generation will require the collection of information on both the supply and demand side.

Objectives

The general objective of this study is to identify socioeconomic characteristics of farmers who choose to adopt a new type of crop and to investigate the factors that might influence an individual producers' choice to grow switchgrass. More specifically, this study will investigate the current attitudes of adopter's verses non-adopters towards the production of switchgrass as an alternative crop.

The study then goes on to develop a model to test whether farmers who are unsure about growing switchgrass would have a propensity to choose to grow switchgrass if given more information. This study will provide information on potential supply of switchgrass by assessing producers' views on switchgrass markets, their willingness to produce switchgrass, the net returns required for them to grow switchgrass. It will then estimate acreage amount and type of agriculture production that might be converted to switchgrass production. It will also provide the likely adoption rate of switchgrass by

Tennessee farmers who answered ‘Do not know, but would like more information’ regarding interest in growing switchgrass if profitable.

References

Burden, D. 2003. Switchgrass Industry Profile. Agricultural Marketing Resource Center.

De La Torre Ugarte, D., G., M.E. Walsh, H. Shapouri, and S.P. Slinsky. 2003. The Economic Impacts of Bioenergy Crop Production on US Agriculture. U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 816.

English, B., D. De La Torre Ugarte, R. J. Menard, C. Hellwinckel and M. Walsh. November 2004. An Economic Analysis of Producing Switchgrass and Crop residues for Use as a Bio-energy Feedstock. Biobased Energy Analysis Group. <http://beag.ag.utk.edu/pp/Sungrant%20Switchgrass%20Final.pdf>

Janick, J., M.G. Blase, D.L. Johnson, G.D. Joliffe, and R.L. Myers. 1996. Diversifying U.S. crop production. P. 98-108. In: J. Janick (ed.), Progress in new crops. ASHS Press, Alexandria, VA.

Joliffe, G.D. and S.S. Snapp. 1988. New crop development: Opportunity and challenges. J. Prod. Agr. 1:83-89.

Joliffe, Gary D. 1997. Policy Considerations in New Crops Development. Oregon Agricultural Experiment Station. Corvallis, Oregon.

McLaughlin, S., J. Bouton, D. Bransby, B. Conger, W. Ocumpaugh, D. Parrish, C. Taliaferro, K. Vogel, and S. Wulschleger, 1999. "Developing Switchgrass as a Bioenergy Crop," in Perspectives on New Crops and New Uses. J. Janick (ed). ASHA Press; Alexandria, VA.

National Campaign for Sustainable Agriculture Inc. <http://sustainableagriculture.net>

Schaller, N. 1993. The Concept of Agricultural Sustainability. Agri. Ecosyst. Env., 46:89-97.

Union of Concerned Scientists (UCSUSA). http://ucsusa.org.food_and_environment/sustainable_agriculture/page.com

US Department of Energy. Energy Efficiency and Renewable Energy. <http://www.eere.energy.gov/>

Part 2: Evaluation of Socio-Economic Characteristics of Farmers Who Choose to Adopt a New Type of Crop

Introduction

As modern agriculture developed, the production of crops became much more mechanized and input intensive. As technology and genetic manipulation through plant breeding and biotechnology increased, specialization occurred. As a result, there has been an increasing emphasis on fewer and fewer commodity crops across the country. In many regions farmers are reliant on just one or two crops for their income. Nearly 80% of the nation's annual row crop acreage is planted to wheat, corn, and soybeans. As a result of this concentration, many growers have few alternatives, and low prices on major commodities have had disastrous economic effects (Joliffe, 1997). At the same time, there has been under-investment in the development of economically viable alternative crop choices for farmers in sustainable farming systems. Rather, the focus has been on increasing yields and decreasing the production costs of traditional crops. Over the last four decades, low prices for major commodities, punctuated by brief periods of prosperity, have reestablished concerns about profitable crop alternatives (Joliffe, 1997).

The continued strength of the environmental movement has spurred interest in a more sustainable and diversified agriculture while consumer demand for new foods and products has increased as a result of changing demography and health concerns (Janick et al, 1996). Throughout history, people have faced the challenge of balancing food production with protection of the environment. More recently, interest in sustainability has risen in response to environmental crises and health hazards. While the nation's land resource seems infinite, it and its production capacity have a limit. According to the USDA, given that a finite supply of natural resources exist, agriculture that is inefficient

will eventually exhaust the available resources or the ability to afford and acquire them. Agricultural production also generates negative externalities, such as erosion and chemical pollution. Agriculture that relies mainly on inputs that are extracted from the Earth's crust or produced by society, contributes to the depletion and degradation of the environment. Despite this continuing practice, unsustainable agriculture continues because it is financially more cost-effective than sustainable agriculture. The profitability of sustainable versus conventional farming is often the most contentious issue encountered when the subject of sustainability is discussed (National Campaign for Sustainable Agriculture).

On a regional or national level, it appears that more widespread adoption of sustainable agriculture can meet many of the government's stated policy objectives for agriculture. Studies conducted by The Sustainable Agriculture Research and Education program (SARE) indicate that total net farm income would increase, government subsidy payments could decline, environmental damage would decline, food quality would improve, and rural employment possibilities rise. Potential problems that could develop include a decline in export of major commodities such as wheat (due to diversification of production and reductions in quantities produced), dislocations in the farm input supply sector, and a shortage of skilled labor, manure and sources of potassium (Ecological Agriculture Projects).

The need for new crop development has been well documented (Holmes 1924; Joliffe 1989; Joliffe and Snapp 1998). More than a century ago, writers were noting the needs and opportunities for profitable new crop alternatives for U.S. farmers. In 1775, in a letter to Thomas Jefferson, George Washington wrote:

Neither my overseers nor manager will attend properly to anything but the crops they have usually cultivated; and in spite of all I can say, if there is the smallest discretionary power allowed them they will fill the land with corn, although even to themselves there are the most obvious traces of its baneful effects. I am resolved, however, as soon as it shall be in my power to attend a little more closely my own concerns, to make this crop yield in a degree to other grains, to pulses, and to grasses (Rasmussen 1975).

Historically, U.S. agricultural policy has lacked a strategic plan to develop profitable new crop options for U.S. farmers and the national good. There have been several abortive attempts to develop new crops, but these have been crisis-based and lacked the organizational structure, support, and commitment within a congressionally mandated strategic plan (Joliffe, 1997). These programs have been enormously expensive. An estimate of the costs from 1978 to 1994 is more than \$291 billion (in 1987 dollars). Adding interest, lost crop wealth opportunities, and multiplier effects will more than double the costs to U.S. taxpayers (Joliffe, 1996). Payments in turn are distributed unevenly among the various agricultural sectors. Yet despite these programs, farm numbers, farm populations, and rural prosperity continue to decline ominously (Janick et al. 1996). According to The Agriculture Policy Analysis Center (APAC), U.S. agriculture has been characterized as an industry with surplus resources. These resources

are not likely to leave agriculture as they would in other industries. Agriculture resources have little alternative used in other areas of production. Therefore, agriculture is economically depressed (Ray, 2002).

In the 1990 Farm Bill, the U.S. Congress approved the creation of the Alternative Agricultural Research and Commercialization Center (AARC) within the USDA. During the first three years of operation, most of the Center's resources were devoted to joint-venture commercialization projects related to new uses of existing agricultural commodities. Only 15% of available funds have been awarded to new crop development. Other federal programs that support new crop development can be found in the Agricultural Research Service (ARS) or are supported by small grants administered by the Cooperative State Research, Education, and Extension Service (CSREES). The negligible amount of funding for new crops research within the USDA underscores the need for a national commitment to new crops-specific development, with direct funding sources within budgets or within organizations (Joliffe, 1996).

Biomass

Biomass is a renewable energy resource. It can be derived from the carbonaceous waste of various human and natural activities. Derived from numerous sources, including the by-products from the timber industry, it can also consist of agricultural crops and raw material from the forest, as well as major parts of household waste and wood.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are

now burning fossil fuels or converted to transportation fuel through gasification, pyrolysis, or fermentation. Currently, biomass is an important source of energy and the fourth most important fuel worldwide after coal, oil and natural gas (U.S. Department of Energy).

In 2003, biomass was the leading source of renewable energy in the United States, providing 2.9 Quadrillion Btu of energy. Biomass was the source for 47% of all renewable energy or 4% of the total energy produced in the United States (U.S. Department of Energy). Agriculture and forestry residues, and in particular residues from paper mills, are the most common biomass resources used for generating electricity, and industrial process heat and steam and for a variety of biobased products. These are the organic byproducts of food, fiber, and forest production. Current biomass consumption in the United States is dominated by industrial use, largely derived from wood. Use of liquid transportation fuels such as ethanol and biodiesel, however, currently derived primarily from agricultural crops, is increasing dramatically. In 2003, ethanol produced from corn reached 2.81 billion gallons and is projected to reach 3.496 billion gallons in 2006 (U.S. Department of Energy; Energy Information Administration).

Many farmers already produce biomass energy by growing corn to make ethanol. But biomass energy comes in many forms. Virtually all plants and organic wastes can be used to produce heat, power, or fuel. Biomass energy has the potential to supply a significant portion of America's energy needs, while revitalizing rural economies, increasing energy independence, and reducing pollution. Farmers would gain a valuable new outlet for their products (De La Torre Ugarte et al, 2003; English et al, 2002). Rural communities could become entirely self-sufficient when it comes to energy, using locally

grown crops and residues to fuel cars and tractors and to heat and power homes and buildings (Union of Concerned Scientists, 2005).

Opportunities for biomass energy are growing. For example, several million dollars of federal incentives are available through the 2002 Farm Bill to develop advanced technologies and crops to produce energy, chemicals, and other products from biomass. A number of states also provide incentives for biomass energy.

Crops grown for energy could be produced in large quantities, just as food crops are. While corn is currently the most widely used energy crop, native trees and grasses are likely to become the most popular in the future. These perennial crops require less maintenance and fewer inputs than do annual row crops, so they are cheaper and more sustainable to produce.

A joint study with The University of Tennessee, the Oak Ridge National Laboratory (ORNL), and the USDA found that farmers could grow 188 million dry tons of switchgrass on 42 million acres of cropland in the United States at a price of less than \$50 per dry ton delivered. This level of production would increase total U.S. net farm income by nearly \$6 billion. ORNL also estimates that about 150 million dry tons of corn stover and wheat straw are available annually in the United States at the same price, which could increase farm income by another \$2 billion. This assumes about 40 percent of the total residue is collected and the rest is left to maintain soil quality (De La Torre Ugarte et al, 2004).

Switchgrass

Switchgrass is a potential feedstock source for producing bioenergy. Switchgrass is a perennial grass that is native to North America and can be managed using common agricultural practices. Using switchgrass as a feedstock in the production of energy generates fewer atmospheric emissions, especially sulfur. Switchgrass also adds organic matter to soils and can help reduce erosion on highly erodible lands. Furthermore, switchgrass can provide valuable habitat for wildlife (McLaughlin, et al., 1999).

Switchgrass production can benefit farmers, taxpayers, industrial-fiber producers, energy producers and consumers of energy. Bioenergy can be produced by co-firing switchgrass with coal to produce electricity in existing power plants. This offers a near term energy production alternative, as does the use of switchgrass as a feedstock in bio-reactors that produce bio-based fuels or industrially important chemicals (Burden, 2003; English et al, 2004).

There are several environmental benefits to switchgrass production for biomass. Once established it is maintained using a minimal level of inputs. With respect to energy production, switchgrass as a crop sequesters carbon, therefore reducing atmospheric carbon-dioxide content when used in place of coal (Agricultural Marketing Resource Center).

The use of switchgrass for energy production is still in the experimental stages and as a result the market for switchgrass is not developed. Assessing the feasibility of switchgrass production for energy generation will require the collection of information on both the supply and demand side.

Objectives

Profitable new crop alternatives have been needed by U.S. farmers for most of the peacetime history of the nation. New or alternative crops can be beneficial to both American agriculture and to society. Understanding the factors affecting a farmer's decision to adopt a new crop is essential in developing strategies to commercialize various new crops that may benefit the economy.

The general objective of this study is to identify socioeconomic characteristics of farmers who choose to adopt a new type of crop. More specifically, this study will investigate the current attitudes of adopter's verses non-adopters towards the production of switchgrass as an alternative crop. This study will provide information on potential supply of switchgrass by assessing producers views on switchgrass markets, their willingness to produce switchgrass, the net returns required for them to grow switchgrass, and the acreage amount and type of agriculture production that might be converted to switchgrass production.

New Crop Adoption

The contribution of new technology to economic growth can only be realized when and if the new technology is widely diffused and used. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it. An understanding of the factors affecting this choice is essential both for economists studying the determinants of growth and for the creators and producers of such technologies (Hall and Khan, 2003).

Advances in agricultural technology have often been associated with productivity growth and lower agricultural commodity prices. Furthermore, these changes have been related to a reduction in farm numbers and increased farm size. Understanding the process of technology adoption helps researchers determine potential scale effects of new technology, as well as who may benefit from technical change.

Part of the gain from agricultural productivity growth is transferred to consumers and other sectors of the economy through increased production and lower prices. However, the distribution of gains from new technology among agricultural producers may be uneven. Early adopters of new technology may realize increased profits, at least in the short run. As more farmers adopt the technology, the increase in aggregate supply causes agricultural prices to fall, which can reduce farmer profits. Farmers who have adopted the new technology are less likely than non-adopters to be driven out of business because the technology may also reduce their production costs. To remain in business, non-adopters may be compelled to adopt the new technology. This cycle of technological advance, supply increase, price decrease, and structural readjustment is often referred to as the "technology treadmill" (Economic Research Service, 2002).

There are concerns that technology development may squeeze small farms out since certain types of technology may be more easily adopted on larger farms. Some yield-increasing technologies may also be more rapidly adopted by very large farms, which may be able to acquire information or other inputs at lower cost, or receive higher prices for their products than smaller farms. These factors may lead large farms to adopt any new technology more rapidly than small farms, regardless of the characteristics of the new technology (Economic Research Service, 2002).

One important aspect to observe about adoption of new technologies is that at any point in time the choice being made is not a choice between adoption and not adoption but a choice between adopting now or deferring the adoption decision until later. The benefits from adopting a new technology are flow benefits which are received throughout the life of the acquired innovation. However, the costs are typically incurred at the time of adoption and cannot be recovered. Therefore, a potential adopter weighs the fixed costs of adoption against the benefits he expects (Hall and Khan, 2003).

Characteristics of the New Crop Adoption Process

The incentives behind new crop development in the past have often not been commercial, that is, they have borne little relationship to the creation of value, directly. However, if personal motivation is realistically targeted in a commercial sense, appropriate community, regional, and national incentives can follow.

According to a study by Fletcher, farmers who adopt new crops are often motivated by a need to improve or stabilize income over a region or on a single farm. In order for incomes to stabilize with new crop production, the new crop products need to satisfy the needs of the consumer. New crop participants often cannot accept that a commercially successful new crop product takes time to develop and the risks are high. Public interest in new crops increases during crises, especially if sudden reorganization is being forced upon the primary industry sector. Such interest is encouraged by the news media with stories of potential “windfall” profits which cannot be verified or guaranteed (Fletcher, 2002).

Capturing these windfall profits is a strong motivation behind the adoption of a new crop. Farmers may view new crop production as offering a high return. Educating farmers about the realities and risks associated with new crop production may help erase any confusion or ignorance about certain claims made about new crops.

Prospectus-driven and tax management schemes often feature new crops but commercially viable new crop products are not necessarily their principal motivation; such schemes provide flexibility for those with substantial income tax obligations. The schemes are promoted in these terms. The new crop product itself often fails before it reaches the farm gate because the promoter and/or the manager do not have the skills, motivation or desire to properly nurture the development of the product (ASIC 1998).

One approach to identify the principal motivations of new crop production by using a survey can be seen in a study by Fletcher. This study found that the most frequently declared purpose amongst new crop participants in Australia, initially, has been their desire to introduce changes to their supply chains or their farming systems, before change is forced upon them. These changes are sought because the participants feel they can do better (Fletcher, 2002).

When asked the purpose of making such a change, participants have usually indicated that the purpose has been to take control of their own future or to improve income. They want to improve the value of their assets before the assets are eventually transferred to the next generation. The principal motivation, once identified, must be the most appropriate basis for subsequent planning (Fletcher, 2002).

Testing the future purpose has also been a useful predictor for new crop participants before they start on any new initiative (Fletcher, 2002). The future purpose

examines whether identifying the principal motivation, pursuing it and achieving it in the time frame specified, represents a worthwhile accomplishment. Community, regional, and national incentives will have some political motivation which may not be focused on value creation. For example, new crop participants can frequently have hidden agendas driven by academic or other purposes, rather than by commercial interest.

There have been a large number of barriers to successful commercialization of new crops, ranging from policy and institutional barriers to a lack of plant breeding and market development. Principal barriers of new crop products include the high risks inherent in establishing a viable supply chain for a new crop product, the lack of reliable information about the available new crops options and the long lag period before profits are forthcoming, if they come at all (Wood et al. 1994).

It is difficult to estimate future demand and price levels for any new crop product, because new crop market systems will almost certainly be chaotic. The relationship between such factors as supply, demand and price for new crop products can be volatile. Also, many new crop products do not easily substitute for others.

A study by Purdue University found that international new crop adoption cannot be predicted accurately because marketing and economic factors are chaotic in their behavior and highly differ in their demographic area (Fletcher 2002). This suggests that model specification of the motivations and influences for new crop adoption plays a crucial role in determining whether or not there is a possibility for new crop adoption.

One study by Iowa State University researched the motivations behind, obstacles to, and consequences of adoption of alternative farming practices in southern Iowa's Chariton Valley. This study concluded that there were too many inconsistencies between

knowledge, attitude, and practice, as well as issues of equality, to devise strategies that would predict an accurate estimate of what motivates farmers' adoption motivations (Hippie & Duffy 2002).

Geographical and location and resource availability frequently are factors that influence the adoption decision. One study conducted by Auburn University examined the interest among Alabama farmers in growing switchgrass for energy. This study found that interest in adoption increased in the areas in Alabama that are more suitable for switchgrass production (Bransby 1999).

Extensive economic and agronomic research is currently underway at Iowa State University and The University of Tennessee to assess and increase the viability of switchgrass as a biomass crop. Iowa State University's research efforts focus on: (1) the economic potential of switchgrass as an agronomic crop for bioenergy, documenting on-farm costs and resource commitments for switchgrass production, assessing regional economic impacts of large-scale switchgrass production; (2) switchgrass production in relation to soil variability and environmental quality, identifying landscape and nitrogen effects on switchgrass production potential; and (3) evaluation and development of switchgrass germplasm for bioenergy production and adaptation to Iowa (Brummer 1998). The University of Tennessee's research efforts focus on: (1) the development of best agronomic practices for switchgrass production over a variety of landscaped soils; (2) how many acres could be available for energy production crops; (3) what prices are needed to entice farmers to plant energy crops; (4) where is the energy crops production most competitive with traditional crops; (5) what effects will large-scale production of energy crops have on the prices and quantities of traditional agricultural crops; (6) how

will production of energy crops affect net farm returns; and (7) how might agricultural and energy policies affect energy crops production.

Limitations in knowledge about the factors influencing new crop adoption have not accurately explained specific motivations. Further, little analysis has focused on the adoption rates of new crops by farmers in Tennessee.

Methodology

Data Collection

A mail survey titled “Tennessee Farmer’s views on switchgrass production for energy” was conducted in March and April of 2005 to examine whether farmers are willing to adopt switchgrass as a new crop. The field survey randomly sampled Tennessee farmers making more than \$10,000 a year in agricultural commodities (Jensen et al, 2005).

A total of 15,002 farmers were contacted by a mail survey consisting of 27 questions (Appendix A). A questionnaire was developed to query Tennessee farmers in all counties about their ability, attitudes, and willingness to adopt switchgrass as a new crop used for energy, as well as their demographic information. The questions addressed four major areas: 1) the knowledge and interest of switchgrass as an energy crop; 2) the characteristics of the farm operation, including types of enterprises and use of various agricultural practices; 3) farm income; and 4) socio-demographic characteristics of the farmers.

Following procedures outlined in Dillman’s Tailored Design Method (Dillman, 2000), the questionnaire, a postage-paid return envelope, and a cover letter explaining the

purpose of the survey were sent to randomly selected Tennessee farmers. The initial mailing of the survey occurred in Mid-March and a reminder postcard was sent one week later. A follow-up mailing to farmers not responding to the first inquiry was conducted 3 weeks later. The second mailing included a letter indicating the importance of the survey, the questionnaire, and a postage-paid return envelope. The survey contained statements about individual responses being confidential. All surveys were sent by the Tennessee Agricultural Statistics Service (TASS) and surveys that were returned were coded by the Institute of Agriculture's Human Dimensions Laboratory.

Statistical Analysis

The similarity of farm and farm characteristics are compared between survey respondents that answered 'Yes, I would be interested' and 'No, I would still not be interested' to a survey question about interest in growing switchgrass. The farm characteristic variables for each group were assessed separately using T-tests. T-tests were used to test the differences in means for all continuous variables. The t statistic is calculated as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - m}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}},$$

df = minimum of $n_1 - 1$, $n_2 - 1$

where s_p^2 is the pooled variance from the two groups:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

And m is a constant to which the differences in means are compared. To test whether the variances are unequal, the F statistic is used where

$$F' = [\max (s_1^2, s_2^2) / \min (s_1^2, s_2^2)]$$

If variances are unequal, then the t statistic becomes:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{w_1 - w_2}}$$

Where $w_1 = [(s_1^2)/(n_1)]$ and $w_2 = [(s_2^2)/(n_2)]$.

The chi-square test was used to test the difference in frequency of occurrence for all categorical characteristic variables. The chi-squared statistic is computed as:

$$Q_p = \sum_i \sum_j \frac{(n_{ij} - e_{ij})^2}{e_{ij}}$$

Where

$$e_{ij} = \frac{(n_i n_j)}{n}$$

Q_p has an asymptotic chi-square distribution with $(R-1)(C-1)$ degrees of freedom.

The null hypothesis for each case is that there is no difference in a characteristic variable between respondents who are interested in growing switchgrass and those who are not.

Results

Of the total 15,002 surveys were mailed to Tennessee farmers, 282 were returned undeliverable, 90 were returned by addressee for reasons other than the addressee was no longer capable of farming, and 102 were returned because addressee was no longer

capable of farming. Of the remaining 14,720 potential respondents, data were obtained from 3,499 units for a response rate of 23.79%. While socio-economic data were not available for non-respondents, information about location was available. Chi-Squared tests were used to evaluate the association between urban/rural county and response and also region within the state response. No significant degree of association was found between either of these locations variables and response, suggesting no geographically related non-response bias.

Comparing statistics from respondents with state statistics, it appears that the respondents were older than the average for farmers in the state. As seen in Table 1, the state average net farm income for 2004 was \$11,331. Most of the respondents (49%) indicated that they fell into a 0 to \$9,999 category. Finally, it appears that more respondents ($\approx 30\%$) have a college degree than the farm state average ($\approx 20\%$).

Grower Profile

A general profile and characteristic summary of the population of farmers surveyed is found in Table 2. The average size of surveyed farms is 221 acres. This is slightly higher than the 2002 Tennessee Census of Agriculture average of 133 acres. However, this is to be expected as the sample did not include farms with sales of less than \$10,000. The average age for the sample is 60 years, which compares favorably to the census average of 56. Forty nine percent of sampled farmer's net farm income is under \$10,000 which is within range of the census average net farm income of \$3,446. Eighty-eight percent of surveyed farmers had at least a high school diploma, which is slightly

Table 1. Characteristics of survey respondents and statewide census.

Characteristics	Survey Respondents	All Tennessee State Farmers
Net Farm Income After Taxes		
Negative (Less than \$0)	15.42%	Average is \$11,331
\$0 - \$9,999	49.32%	
\$10,000 - \$ 14,999	14.39%	
\$15,000 - 24,999	9.96%	
\$25,000 - \$34,999	4.80%	
\$35,000 - \$ 49,999	2.60%	
\$50,000 - \$74,999	1.73%	
\$75,000 - \$99,999	0.80%	
\$100,000 - \$149,999	0.53%	
Greater than or equal to \$150,000	0.47%	
Education Level Obtained:		
Some High School or Less	12.44%	24.10%
High School Graduate	38.12%	31.60%
Some College	19.89%	24.80%
College Graduate	16.40%	19.60%
Post Graduate	13.15%	
Age:		
15 years to 44 years	11.32%	45.21%
45 to 64 years	50.46%	34.29%
65 or older	38.22%	20.50%
Sources: Economic Research Service, USDA		

Table 2. Farm and farmer characteristics for the sample.

Item Measured	Mean
Total Acres:	221.11 acres
Acres owned	156.46 acres
Acres rented	53.18 acres
Acres rented to others	12.15 acres
Total acres farmed	198.18 acres
Net Farm Income (2004):	
Negative (less than \$0)	15.35%
\$0 - \$9,999	49.31%
\$10,000 - \$14,999	14.41%
\$15,000 - \$24,999	10.00%
\$25,000 - \$34,999	4.75%
\$35,000 - \$49,999	2.63%
\$50,000 - \$74,999	1.75%
\$75,000 - \$99,999	.81%
\$100,000 - \$149,000	.54%
Greater than or Equal to \$150,000	.47%
Net income from off-farm sources	52.19%
Age of Operator	60 years
Farm Experience	38.72 years
Highest Education Level Attained:	
Some high school or less	12.31%
High school graduate	38.32%
Some college	19.95%
College graduate	16.44%
Post graduate	12.97%
Type of Farming Business:	
Full owner	78.34%
Part owner	18.04%
Renter	2.20%
LLC	.40%
Cooperative	.06%
Lease out	.25%
Other	.71%

higher than the state census average of 77%. Sole proprietorship comprised of 78% of farmers surveyed which is considerably lower than the census average of 94%.

Stated Knowledge and Interest in Switchgrass

General knowledge and interest in switchgrass is found in Table 3. Of the surveyed farmers, 20.8% have heard of switchgrass as a crop for energy production. If profitable, 29.6% of sampled farmers would be interested in growing switchgrass, while 23.7% would not be interested. The remaining sampled farmers (46.7%) did not have previous knowledge of switchgrass, but were interested in obtaining more information(N=3,244). There was a significant association between a respondents stated knowledge about switchgrass and the respondents' interest in growing switchgrass ($\chi^2 = 44.6$ with 2df). Table 4 shows that 38.9% of respondents who have heard of switchgrass would be interested in growing switchgrass while 27.2% of respondents who have no knowledge of switchgrass were interested (N=3,229).

Net Returns and Converted Acreage

Respondents who stated that they were interested in growing switchgrass stated that, on average, the minimum net profit per acre that would be required to interest them in growing switchgrass was \$415.62. If this profit is obtained, the interested sampled farmers would consider growing an average of 67.3 acres of switchgrass. This acreage represents roughly 28% of farmland. The distribution of the net returns per acre were skewed by a few large values, therefore the mean value is considerable larger than the median value of \$200 per acre. The median for acres to be converted to switchgrass is slightly less than 49 which is considerably lower than the mean value.

Table 3. Farmer's views and knowledge on switchgrass.

	Percent			
Have heard of growing switchgrass as a crop for energy production	20.8 (N=3,312)			
Interested in growing switchgrass if profitable	29.6 (N=3,244)			
Not interested in growing switchgrass if profitable	23.7 (N=3,244)			
Do not know but interested in obtaining more information	46.7 (N=3,244)			
	Mean	Standard Deviation	Median	N
Minimum net profit per acre needed for interest in growing switchgrass (\$)	415.62	1,635.99	200.00	697
If profit obtained, acres of switchgrass considered for planting	67.33	87.2	48.5	684
Acres farmed by individuals considering planting switchgrass	236.27	260.66	160.00	623
Proportion of acres farmed to be converted to switchgrass	27.90%	-	28.12%	623

Table 4. Stated knowledge and interest in growing switchgrass.

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

The sum of the acreage that all of the respondents would be willing to convert was 46,033 acres. The percentages of land by type that would be converted are shown in Table 5. Acreages converted by type can be found by multiplying the percentages of land type by the total acreage that would potentially be converted (46,033). Hay and pasture comprise the majority of converted acreage at over 68 percent, followed by corn and soybeans.

Farmer Characteristics

The average respondent was 60 years old (N=3,237) and had 39 years of farming experience (N=3,016). Consistent with national and statewide patterns, the sample had a relatively large share of older farmers and more experienced farmers. Respondents who were interested in growing switchgrass were slightly younger with less experience. This group had an average age of 57 (N=953) and their experience averaged to 36 years (N=915). Farmers who were not interested in growing switchgrass were older and more experienced with an average of 65 years of age (N=694) and 42 years of experience (N=620).

Farming was the primary source of net income for 2004 for 48% (N=2,763) of all respondents. There was no significant difference in the primary source of net income for the two groups. Interested respondents indicated that 52% (N=878) of their primary net income came from off-farm sources, while 49% (N=538) of primary net income came from off-farm sources for non-interested respondents.

The majority of respondents were a high school graduate (38.3%), with 20% having had some college but no college degree and 29% having a college degree or more.

Table 5. Types of acreage that might be converted to switchgrass.

Crop or Other Use	Percent of Acres (N=786)	Acres
Hay	41.43	19,071.1
Pasture	26.86	12,362.8
Soybeans	11.95	5,499.5
Corn	10.88	5,007.9
Cotton	1.97	906.3
Wheat	1.82	837.7
CRP	1.04	479.7
Tobacco	1.00	458.2
Idle	0.74	338.8
Forest/Woodland	0.65	300.7
Other Grains	0.60	277.4
Nursery	0.46	212.4
Vegetables	0.34	158.0
Other Acres	0.24	109.7
Fruit	0.03	13.1
Total	100.00	46,033.0

Interested respondents had more education with 38% as college graduates, while non interested respondents showed had less education with 21% being college graduates (Table 6).

As seen in Table 7, personal computers were owned by approximately 70% of the survey respondents. Seventy four percent of interested respondents owned a personal computer while only 42.1% of non-interested respondents owned a personal computer. On average, respondents attended 0.8 extension workshops or experiment station field days per year. Interested respondents have a higher attendance of 1.06 days per year, while non interested respondents have a lower attendance of 0.46 days per year. Approximately 77% of respondents were members of Farm Bureau and 50% were members of a cooperative. As seen in Table 7, interested respondents had a higher percentage belonging to organizations and non interested respondents had a lower percentage belonging to organizations. Interested respondents have a slightly higher

Table 6. Distribution of educational attainment.

Education Level	All Survey Respondents (N=3223)	Interested Respondents (N=948)	Not Interested Respondents (N=684)	Don't Know Respondents (N=1489)
<i>Percent</i>				
Some High School	12.3	8.0	19.6	10.8
High School	38.3	32.0	40.9	41.2
Some College	20.0	21.7	18.6	19.8
College	16.4	21.9	10.2	16.3
Post-Graduate	13.0	16.4	10.7	11.8

Table 7. Farmer's behaviors.

Behavior	All Survey Respondents	Interested Respondents	Not Interested Respondents	Don't Know Respondents
<i>Percent</i>				
Currently issue hunting leases on land	8.7 (N=3,229)	11.1 (N=943)	5.0 (N=698)	8.6 (N=1,489)
Own a personal computer	60.9 (N=3,212)	73.9 (N=948)	42.1 (N=692)	62.4 (N=1,472)
Times per year attend extension workshops or experiment station days	.80 (average days) (N=2,832)	1.06 (average days) (N=842)	.46 (average days) (N=612)	.79 (average days) (N=1,295)
Currently belong to the following organizations:				
Grower/commodity organizations	5.2 (N=3,271)	7.3 (N=956)	4.0 (N=706)	4.4 (N=1,504)
Cooperatives	49.5 (N=3,271)	55.5 (N=956)	38.7 (N=706)	51.1 (N=1,504)
Farm bureau	76.7 (N=3,271)	76.5 (N=956)	71.5 (N=706)	79.4 (N=1,504)
Hunting related organizations	10.3 (N=3,271)	14.2 (N=956)	5.0 (N=706)	10.2 (N=1,504)
Environmental organizations	4.5 (N=3,271)	7.5 (N=956)	1.7 (N=706)	4.0 (N=1,504)

percentage of respondents issuing hunting leases on their land when compared to non interested respondents.

Farm Characteristics

For all respondents, the average acreage farmed was just over 204 acres (N=3,068) for a total of 626,457 farmed acres. Approximately 27% of total acres farmed were leased from another party while approximately 6% of total acres were leased to another party. The average rental rate estimated by producers was \$74 an acre (N=1,228). The average acreage farmed for respondents interested in growing switchgrass is relatively the same to the overall averages (N=924). The interested respondents own approximately 68% of the acres farmed. Roughly 27% is rented from another party and 5.1% is rented to another party. Respondents who were not interested in growing switchgrass have a higher average of acreage owned than those who were interested. Approximately 78% own the acres farmed (N=666). Roughly 18% of the farmed land was rented from another party while 4.5% is rented to another party.

Approximately 47.3 percent of all respondents indicated that they have no significant erosion problem on their land. Thirty-nine percent of the respondents who are interested in growing switchgrass stated no erosion problem, while 61.1% of non interested respondents stated no erosion problem on land (Table 8). A majority of respondents (74.8 percent) owned hay equipment (N=3,262). Approximately 76 percent of interested respondents (N=952) owned hay equipment while only 64.3 percent of non interested respondents (N=704) owned hay equipment. Among these respondents, 97.8 percent owned a mower (N=2,434), 94.4 percent owned a rake (N=2,432), 75.4 percent

Table 8. Farm's current situation.

Farm's Current Situation	All Survey Respondents (N=2,950)	Interested Respondents (N=887)	Not Interested Respondents (N=592)	Don't Know Respondents (N=1,394)
	<i>Percent</i>			
Currently has CCP	18.7	23.7	13.2	17.5
No CCP, but erosion control	29.2	32.5	22.3	30.2
No erosion problem	47.3	38.8	61.1	47.1
Erosion program but not used currently	4.7	5.1	3.4	5.2

owned a round baler (N=2,434), and 49.2 percent owned a square baler (N=2,433). Percentages of the types of hay equipment do not vary much within the two responding groups. Table 9 shows the distribution of equipment for the groups. Among those with round balers, about 47.6 percent had small bale size balers (less than 1,000 pounds or less than 5 foot by 5 foot), 47.3 percent had a medium size baler (1,000 to 1,900 pounds or 5 foot by 6 foot), and 5.1 percent had a large size baler (greater than 1,900 pounds or 6 foot by 6 foot) (N=1,633). For respondents with square balers, 49.9 percent has small balers (less than 24 inch), 41.7 percent had medium balers (24 to 36 inch), and 8.4 percent had large balers (greater than 36 inch) (N=769). Almost all respondents who owned hay equipment (96.9 percent) used twine to secure their bales (N=2,011). The distribution of type of balers within interested and non interested respondents is shown in Table 9. About 30.4 percent of the respondents had used custom hay harvest services (N=3,140). The most commonly reported prices for these services were \$10 per acre for mowing/raking, \$8 per bale for round baling, \$6 per bale for baling large square bales, and \$1 per bale for baling small square bales.

Table 9. Information on hay equipment.

	All Survey Respondents (N=3,357)	Interested Respondents (N=959)	Not Interested Respondents (N=770)	Don't Know Respondents (N=1,515)
<i>Percent</i>				
Own hay equipment	74.8	75.8	63.3	79.3
Mower	97.8	98.3	97.8	97.6
Rake	94.4	95.4	92.0	94.9
Round baler	75.4	77.3	70.5	76.3
Square baler	49.2	53.2	47.2	48.0
Type of wrap used with baler:				
Twine	96.6	95.6	96.9	97.0
Wire	0.0	0.0	0.0	0.0
Net	1.2	1.1	2.0	1.1
Twine and net	1.7	2.8	0.9	1.5
Not wrapped	0.2	0.2	0.3	0.3
Other	0.1	0.3	0.0	0.1
Have used custom hay services	30.4	34.6	25.3	29.9
<i>Average cost of service per acre (\$)</i>				
Mowing/raking	16.16	16.43	12.50	16.48
Baling for round bales	15.66	10.89	11.45	20.75
Baling for small square bales	8.11	6.36	1.00	12.14
Baling for large square bales	12.66	16.60	12.33	8.79

Approximately 44.1 percent of all respondents indicated that they used no-till production practices (N=3,055). Fifty six percent of the interested respondents (N=907) indicated the use on no-till production methods, while only 29.4 percent of non-interested respondents (N=642) use no-till production methods.

The majority of respondents had livestock on their farms. Most had cow/calf operations which represented 78.6 percent of livestock operations. Dairy cattle backgrounding/stockering operations and 9.4 percent had other types of livestock (N=3,273). Included among the other types of livestock operations were poultry, hogs, horses, and goats. Table 10 reports the distribution of livestock operations.

Table 11 shows the distribution of 2004 after-tax net farm income. About 15.3 percent had negative net farm income, while 64.6 percent had a net farm income below \$10,000 (N=2,971). Approximately 14 percent had net farm income between \$10,000 and \$15,000. Respondents who are interested in growing switchgrass showed a slightly higher income level than those who were not.

As shown in Table 12, the majority of the respondents (79.7 percent) did not carry any debt (N=2,941). Another 6.2 percent carried some debt, but less than \$3 for every \$100 of assets. In total, only 9.4 percent carried debt of over \$10 per \$100 of assets. Respondents who were interested in growing switchgrass showed a slightly higher amount of debt compared to respondents who were not interested in growing switchgrass. Approximately 78.3 percent of the respondents characterized themselves as full owners (N=3,227). About 18 percent are part owners. There are a slightly higher percentage of full owners for respondents who were not interested in growing switchgrass compared to interested respondents (Table 13).

Table 10. Types of livestock operations.

Livestock	All Survey Respondents (N=3,273)	Interested Respondents (N=952)	Not Interested Respondents (N=710)	Don't Know Respondents (N=1,506)
	<i>Percent</i>			
Beef Cow-Calf	78.6	76.5	75.9	81.1
Dairy Cattle	1.8	1.9	1.5	1.9
Backordering/ Stockering	5.4	8.3	3.5	4.6
Other	9.4	8.1		

Table 11. Net income after taxes from farming in 2004.

Net Income for Farming in 2004	All Survey Respondents (N=2,971)	Interested Respondents (N=893)	Not Interested Respondents (N=630)	Don't Know Respondents (N=1,363)
	<i>Percent</i>			
Negative (less than \$0)	15.3	15.5	17.9	14.6
\$0 - \$9,999	49.3	43.4	52.4	51.5
\$10,000 - \$14,999	14.4	15.1	14.3	13.9
\$15,000 - \$24,999	10.0	11.9	6.8	10.0
\$25,000 - \$34,999	4.7	6.0	3.0	4.6
\$35,000 - \$49,999	2.6	3.1	2.2	2.4
\$50,000 - \$74,999	1.8	2.5	1.7	1.4
\$75,000 - \$99,999	0.8	1.2	0.3	0.7
\$100,000 - \$149,999	0.5	0.7	0.6	0.4
Greater than or equal to \$150,000	0.5	0.6	0.6	0.4

Table 12. Debt to farm assets.

Dollars of Debt for Every \$100 of Farm Assets	All Survey Respondents (N=2,941)	Interested Respondents (N=867)	Not Interested Respondents (N=635)	Don't Know Respondents (N=1,355)
	<i>Percent</i>			
0	79.7	69.2	89.4	81.4
\$1 - \$2.99	6.2	9.2	2.7	6.3
\$3 - \$4.99	2.4	3.8	1.4	2.0
\$5 - \$9.99	2.1	2.9	0.8	2.4
\$10 - \$14.99	2.2	4.2	0.8	1.8
\$15 - \$19.99	1.7	2.7	0.9	1.5
\$20 - \$39.99	2.2	3.5	1.4	2.0
\$40 - \$69.99	1.9	3.0	1.3	1.6
\$70 or greater	1.4	1.6	1.3	1.0

Table 13. Farming business.

Farming Business	All Survey Respondents (N=3,227)	Interested Respondents (N=954)	Not Interested Respondents (N=689)	Don't Know Respondents (N=1483)
	<i>Percent</i>			
Full Owner	78.3	78.6	83.2	75.9
Part Owner	18.0	18.3	12.0	20.7
Renter	2.2	2.2	2.5	2.0
LLC	0.4	0.3	0.3	0.5
Cooperative	0.1	0.0	0.0	0.1
Lease Out	0.2	0.0	0.6	0.3
Other	0.7	0.5	1.5	0.5

Views on Switchgrass Production and Markets

Respondents ranked the extent to which they agreed with a number of statements regarding switchgrass production and marketing on a scale of one to five, with one meaning that they strongly agreed with the statement and five that they strongly disagreed. A summary of the responses is shown in Table 14. The respondents agreed that producing energy from biomass would help reduce air emissions. They also were in agreement with statements that they would need technical assistance on how to grow switchgrass. They also were concerned about the uncertainty of switchgrass markets. Respondents did not perceive a strong conflict between planting or harvesting periods for switchgrass and planting and harvesting of their other crops.

Statistical Results

Table 15 evaluates the statistical difference of farm and farm characteristics between respondents who were interested in growing switchgrass and those who were not. For continuous characteristic variables, the null hypothesis is that the means of the variables are the same for interested and non interested respondents. T statistics are used under the assumption of an equal variance. For categorical variables, chi square statistics are used for the test of homogeneity, and the null hypothesis is that the percentage in each category is the same for interested and non interested respondents. The continuous variables farm size in acres, age, years of farming experience and times attend extension workshops or experiment station field days were statistically significant at the 95 percent confidence level. Respondents interested in growing switchgrass had, on average, more

Table 14. Means of views on switchgrass adoption.

Statements^a	All Survey Respondents	Interested Respondents	Not Interested Respondents	Don't Know Respondents
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive:	2.53 (N=1,653)	2.41 (N=886)	2.79 (N=467)	2.50 (N=262)
Planting period for switchgrass will conflict with planting period for my other crops:	3.29 (N=1,703)	3.51 (N=892)	2.88 (N=466)	3.27 (N=260)
Harvesting period for switchgrass will conflict with harvesting period for my other crops:	3.30 (N=1,641)	3.50 (N=887)	2.91 (N=462)	3.28 (N=255)
Switchgrass can help control erosion on my land:	2.4 (N=1,667)	2.26 (N=901)	2.88 (N=464)	2.58 (N=264)
I am concerned that markets for switchgrass are not sufficiently developed:	2.17 (N=1,676)	2.00 (N=902)	2.54 (N=469)	2.11 (N=267)
Production risk for switchgrass is lower than other crops or products I currently produce:	2.83 (N=1,644)	2.78 (N=890)	2.94 (N=461)	2.85 (N=259)
Switchgrass use in producing electricity or fuels should be subsidized by the government:	2.62 (N=1,667)	2.50 (N=897)	2.88 (N=467)	2.61 (N=265)
I would consider signing long-term contracts to grow switchgrass for energy:	2.66 (N=1,663)	2.25 (N=903)	3.41 (N=461)	2.81 (N=262)
I would need technical assistance regarding growing and harvesting switchgrass:	2.14 (N=1,682)	1.93 (N=915)	2.64 (N=462)	2.04 (N=265)
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions:	2.09 (N=1,677)	1.82 (N=907)	2.60 (N=466)	2.15 (N=265)
I would like to provide more habitat for native wildlife species on my own land:	2.38 (N=1,675)	2.13 (N=909)	2.88 (N=466)	2.35 (N=260)
I would need government payments in order to produce switchgrass:	2.57 (N=1,663)	2.45 (N=903)	2.85 (N=462)	2.54 (N=259)

^a The respondents were asked for each statement to rate their level of agreement based on a scale of 1-5, where 1 means strongly agree, 3 means no opinion, and 5 means strongly disagree.

Table 15. Comparison of selected farm and farmer characteristics across interest in growing switchgrass.

Characteristic	Interested in Growing Switchgrass	Not Interested in Growing Switchgrass	
Categorical:	Percent		Chi-Square
Use No Till (N=1,549)	56.0	29.4	107.2*
Have a Conservation Compliance Plan (N=1,542)	18.9	9.8	23.4*
Have Hay Equipment (N=1,656)	75.8	64.3	25.9*
Have Net Farm Income After Taxes of At Least \$10,000 (N=1,523)	41.1	629.7	20.8*
Are College Graduate (N=1,632)	38.3	20.0	56.1*
Full Owner (N=1,643)	78.6	83.2	5.3*
Have Membership In : (N=1,662)			
Grower/Commodity Organization	7.3	4.0	8.2*
Cooperative	55.5	38.7	46.3*
Farm Bureau	76.5	71.5	5.2*
Hunting Organization	14.2	5.0	37.8*
Environmental Organization	7.5	1.7	28.8*
Have a Personal Computer (N=1,640)	73.8	42.1	169.0*
Have Acreage in (N=1,438)			
Soybeans	13.5	4.5	30.4*
Corn	17.9	8.3	25.8*
Wheat	10.2	3.1	25.2*
Tobacco	17.1	10.5	12.1*
Hay	83.1	77.3	7.5*
Forestry/Woodland	18.8	14.1	5.5*
Vegetables	7.6	5.2	3.1
CRP	1.1	0.4	2.5
Idle	3.3	2.0	2.1
Cotton	1.7	0.9	1.6
Fruit	3.5	2.3	1.6
Nursery	0.5	0.9	1.1
Pasture	44.2	43.4	0.1
Continuous:	Means		T-Statistic
Farm Size in Acres	222.3 (N=909)	141.6 (N=626)	7.61*
Age	56.0 (N=953)	63.9 (N=694)	13.62*
Years of Farming Experience	35.8 (N=915)	42.2 (N=620)	6.93*
Times a Year Attend Workshops or Experiment Station Field Days	1.1 (N=842)	0.5 (N=612)	8.96*

* Indicates Variable is Significant at the 95 percent confidence level

farm and acres. Younger farmers with less experience tended to be more interested in growing switchgrass than those who were not. Respondents who attended more extension workshops and experiment station field days were more interested in growing switchgrass than those who were not interested.

At the 95 percent confidence level, there is a positive association between both the use of no-till production methods and having a conservation compliance program and the respondent's interest to grow switchgrass. Interested respondents had a higher percentage of engaging in these practices. Respondents who owned hay equipment and those who were already producing hay had a higher probability of being interested in growing switchgrass. Willingness to grow switchgrass was significantly associated with the production of certain crops. Tobacco, soybeans, wheat, corn, and forestry/woodland had a positive association with interest in switchgrass production, while cotton, fruits, vegetables, and nursery crops did not show any significant association with interest in growing switchgrass.

Education and memberships in organizations such as grower/commodity organizations, Farm Bureau, cooperatives, hunting organizations, and environmental organizations showed a positive association with interest in growing switchgrass.

Conclusions

The purpose of this study was to determine the influence of socioeconomic characteristics on farmers who choose to adopt a new type of crop. This study analyzed the factors influencing the decision to adopt switchgrass for energy production. A chi-square test of independence was used to determine whether significant differences existed

among interested respondents and non-interested respondents in terms of the selected socioeconomic characteristics.

The farmer socioeconomic variables critical for adoption were from farm size, age, experience, workshop attendance, education, memberships in farming organizations, ownership of hay equipment, and use of no-till production.

The findings of the descriptive analysis indicated the existence of problems in the knowledge of switchgrass. Most farmers were not familiar with growing switchgrass as an energy crop, however many were interested in knowing more about switchgrass production. This result highlights the potential importance of education and outreach programs regarding switchgrass. In addition, those who were aware of switchgrass had attended more Extension service workshops or Experiment Station field days. These results suggest the potential for these educational and industry organizations to provide information about growing switchgrass as an energy feedstock.

References

Agriculture Marketing Resource Center. <http://www.agmrc.org/agmrc/>

Australian Securities and Investments Commission. (ASIC). 1998. The appeal of new industries. Austral. New Crops Newslett. 10:2-3.

Brummer, E.C., C.L. Burras, M.D. Duffy, K.J. Moore, R. Lemus, N. Molstad, V. Nanhon, and V. Weaver. 1998. Switchgrass production in Iowa: Economic analysis, soil suitability, and varietal performance. 1998. Annu. Rpt. Iowa State University, Ames.

Burden, D. 2003. Switchgrass Industry Profile. Agricultural Marketing Resource Center.

De La Torre Ugarte, Daniel G., Marie E. Walsh, Hosein Shapouri, and Stephen P. Slinsky, 2003. The Economic Impacts of Bioenergy Crop Production on US Agriculture. U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 816.

Ecological Agricultural Projects. <http://www.eap.mcgill.ca>

Economic Research Service. United States Department of Agriculture. <http://www.ers.usda.gov/>

English, B. Daniel de la Torre Ugarte, R. Jamey Menard, Chad Hellwinckel and Marie Walsh. November 2004. An Economic Analysis of Producing Switchgrass and Crop residues for Use as a Bio-energy Feedstock. Biobased Energy Analysis Group. <http://beag.ag.utk.edu/pp/Sungrant%20Switchgrass%20Final.pdf>

Fletcher, R. J. 2002. International new crop development incentives, barriers, processes and progress: An Australian perspective. P. 40-54. In: J. Janick and A. Whipkey (eds.), Trends in new crops and uses. ASHS Press, Alexandria, VA.

Hall, B. H. and B. Khan. 2003. Adoption of New Technology. UC Berkley Department of Economics Working Paper E03-330.

Hippie, P.C. and M.D. Duffy. 2002. Farmers' Motivations for adoption of switchgrass. P. 252 -266. In: J. Janick and A. Whipkey (eds.), Trends in new crops and new uses. ASHS Press, Alexandria, Va.

Holms, C.L. 1924. The economic future of our agriculture. J. Polit. Economy 32:505-525.

Janick, J., M.G. Blase, D.L. Johnson, G.D. Jolliffe, and R.L. Myers. 1996. Diversifying U.S. crop production. P. 98-108. In: J. Janick (ed.), Progress in new crops. ASHS Press, Alexandria, VA.

Jolliff, G.D. and S.S. Snapp. 1988. New crop development: Opportunity and challenges. J. Prod. Agr. 1:83-89.

Jolliff, Gary D. 1997. Policy Considerations in New Crops Development. Oregon Agricultural Experiment Station. Corvallis, Oregon.

Jolliff, G.D. 1996. New crops R&D: Necessity for increased public investment. P. 115-118. In: J. Janick (ed.), Progress in new crops. Am. Soc. Hort. Sci., Alexandria, VA.

McLaughlin, S., J. Bouton, D. Bransby, B. Conger, W. Ocumpaugh, D. Parrish, C. Taliaferro, K. Vogel, and S. Wulfschleger, 1999. "Developing Switchgrass as a Bioenergy Crop," in Perspectives on New Crops and New Uses. J. Janick (ed). ASHA Press; Alexandria, VA.

National Campaign for Sustainable Agriculture Inc. <http://sustainableagriculture.net>

Ray, Daryll E. Food and Agricultural Policies of the United States. Proceedings of the Symposia Presented at the Annual Meetings of the American Agricultural Economics Association in Chicago, Illinois. Published May 2002 based on papers from August 2001. <http://apacweb.ag.utk.edu/ppap/pdf/02/BookChapter.pdf>

Rasmussen, W.D. 1975. Agriculture in the United States: A documentary history. Vol.1. Random House, New York.

The Sustainable Agriculture Research and Education Program (SARE). <http://www.sare.org/index.htm>. February 12, 2006.

Union of Concerned Scientists (UCSUSA). http://ucsusa.org.food_and_environment/sustainable_agriculture/page.com. March 13, 2006.

US Department of Energy. Energy Efficiency and Renewable Energy. <http://www.eere.energy.gov/>. February 12, 2006.

Wood, I.M., P.D. Chudleigh, and K.A. Bond. 1994. Developing new agricultural industries: Lessons from the past. RIRDC Research Paper Series 94/1, Rural Industries Rural Research and Development Corporation, Canberra.

Appendix

Switchgrass Production for Energy: Your Views

Biomass (plant materials) currently provides about 3 percent of U.S. energy use (ethanol, electricity). Goals are to significantly increase the use of biomass in the U.S. and research is underway to improve conversion technologies and develop new biomass resources. One potential biomass resource is switchgrass. The purpose of this study is to collect information from farmers regarding their views on switchgrass production. Your participation in this study is completely voluntary. Your individual responses will be held completely confidential. Only summaries of the results will be presented. The survey will take 5-10 minutes to complete.

SWITCHGRASS

1. Have you heard of growing switchgrass as a crop to be used in energy production? (Circle the answer)

Yes

No

2. If profitable, would you be interested in growing switchgrass? (Circle the answer)

Yes, I would be interested (Go to question 3)

No, I would still not be interested (Skip to question 6)

Don't Know, but I would interested in obtaining more information (Skip to question 7)

3. What is the minimum net profit per acre needed to interest you in growing switchgrass?

_____ \$/acre

4. If this profit/acre (the \$/acre you listed in question 3) could be obtained, how many acres of switchgrass would you consider planting?

_____ acres

5. What crops are produced (or other uses) on the land that you would consider converting to switchgrass production? (Please list the crop/use along with acreage you might consider converting)

Crop or other use

Acres

- a. _____
b. _____
c. _____
d. _____
e. _____

- _____

Switchgrass Fast Facts

- Utilization as a biomass resource is an emerging market
- A perennial grass native to North America
- Managed using common agricultural practices
- High yielding, drought tolerant, and requires lower fertilizer and herbicide quantities than traditional crops
- Planting-May to early June and can use no-till practices
- As a perennial, needs to be planted only once every 10 years or more
- Harvested annually, either in a two harvest system or a one harvest system after the first frost, using conventional hay equipment
- Potential environmental benefits:
 - compared to fossil fuels, use of switchgrass for energy produces fewer atmospheric emissions (especially sulfur)
 - adds organic matter to soils
 - can be grown on highly erosive lands and helps reduce erosion
 - provides wildlife habitat
- Eligible crop for CRP acres and can be harvested once every three years with rental payment retention

6. Please rate your agreement with each statement below. (Circle the answer)

Statement	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Switchgrass harvesting limits to once every three years to retain CRP payments is too restrictive	1	2	3	4	5
Planting period for switchgrass will conflict with planting period for my other crops	1	2	3	4	5
Harvesting period for switchgrass will conflict with harvesting period for my other crops	1	2	3	4	5
Switchgrass can help control erosion on my land	1	2	3	4	5
I am concerned that markets for switchgrass are not sufficiently developed	1	2	3	4	5
Production risk for switchgrass is lower than other crops or products I currently produce	1	2	3	4	5
Switchgrass use in producing electricity or fuels should be subsidized by the government	1	2	3	4	5
I would consider signing long-term contracts to grow switchgrass for energy	1	2	3	4	5
I would need technical assistance regarding growing and harvesting switchgrass	1	2	3	4	5
Producing more of our nation's energy from biomass is an effective way to control atmospheric emissions	1	2	3	4	5
I would like to provide more habitat for native wildlife species on my own land	1	2	3	4	5
I would need government payments in order to produce switchgrass	1	2	3	4	5

About your farming operation

7. How many acres did you farm in 2004?

_____ acres Owned
 _____ acres Rented
 _____ acres Other (Please describe: _____)
 = _____ acres Total

8. How many acres of each crop/product did you grow in 2004?

Soybeans _____ acres Fruit _____ acres
 Cotton _____ acres Vegetables _____ acres
 Hay _____ acres Tobacco _____ acres
 Corn _____ acres Wheat _____ acres
 Other (For example pasture, idle, or forest.
 Please describe: _____) _____ acres

9. Please circle the answer that best describes your farm's current situation:
- Currently has a Conservation Compliance Program
 - Does not have a Conservation Compliance Program, but practice erosion control methods
 - No significant erosion problem on farmland
 - Significant erosion control program, but erosion control practices are not used currently
10. How many acres do you have in the Conservation Reserve Program (CRP) planted to
 Grass _____ acres Trees _____ acres
11. What CRP payment rate per acre do you receive \$ _____/acre/year
12. If you rent cropland from someone else, what is the cost per year? \$ _____/acre/year
13. Do you own hay equipment? (Circle the answer)
- No Yes, I have the following (Place an 'X' by each):
- | | | |
|--------------|-------|-------------------|
| mower | _____ | |
| rake | _____ | |
| round baler | _____ | (bale size _____) |
| square baler | _____ | (bale size _____) |
14. If you own a baler, what type of wrap do you use? (twine, wire wrap, baler net wrap, etc.) _____
15. Have you used custom hay harvest services? (Circle the answer)
- No Yes, and the costs were:
- | | |
|-------------------------------|---------------|
| mowing/raking | \$/acre _____ |
| baling for round bales | \$/bale _____ |
| baling for small square bales | \$/bale _____ |
| baling for large square bales | \$/bale _____ |
16. Do you currently use no-till production methods? (Circle answer) Yes No
17. Do you have the following types of livestock operations? (Place an 'X' by all that apply)
- Beef Cow-calf _____ Backgrounding/stockering _____
- Dairy cattle _____ Other (Please describe: _____) _____
18. Do you currently issue hunting leases on your land? (Circle the answer) Yes No

19. Which best describes your farming business (Circle the answer)
- a. A full owner (sole proprietorship)
 - b. A part owner in a partnership, family held corporation, or other corporation
 - c. A renter
 - d. A limited liability corporation
 - e. A cooperative
 - f. Other (Please describe): _____
20. Net income from farming in 2004 (after taxes). (Circle the answer)
- | | |
|-----------------------------|---------------------------------------|
| a. negative (less than \$0) | g. \$50,000-\$74,999 |
| b. \$0-\$9,999 | h. \$75,000-\$99,999 |
| c. \$10,000-\$14,999 | i. \$100,000-\$149,999 |
| d. \$15,000-\$24,999 | j. Greater than or equal to \$150,000 |
| e. \$25,000-\$34,999 | |
| f. \$35,000-\$49,999 | |
21. For every \$100 of farm assets you have, how many dollars are financed with debt? (Circle the answer)
- | | |
|-----------------|----------------------|
| a. \$0 | f. \$15-\$19.99 |
| b. \$1-\$2.99 | g. \$20-\$39.99 |
| c. \$3-\$4.99 | h. \$40-\$69.99 |
| d. \$5-\$9.99 | i. greater than \$70 |
| e. \$10-\$14.99 | |

About You

22. Your age in years _____ Years of experience farming _____
23. What percent of your household's net income (after taxes) came from off-farm sources in 2004? _____%
24. What is the highest education level you attained? (Circle the answer)
- | | |
|-----------------------------|---------------------|
| a. Some high school or less | d. College graduate |
| b. High school graduate | e. Post graduate |
| c. Some college | |
25. Do you own a personal computer? (Circle the answer) Yes No

27. Do you currently belong to any of the following types of organizations? (Circle all that apply)
- a. Grower or commodity organizations
 - b. Cooperatives
 - c. Farm Bureau
 - d. Hunting-related organizations
 - e. Environmental organizations

Thank you for your assistance with this study. Please place the survey in the enclosed postage paid envelope and return by mail. A summary of the results will be made available at <http://beag.ag.utk.edu/link.html> .

Part 3: Factors That Influence the Decision to Adopt Switchgrass for Energy Production

Introduction

Background

In the recent decade, agriculture sustainability has become a popular topic. A sustainable agriculture is generally regarded as an alternative to modern industrialized or conventional agriculture which is described as highly specialized and capital intensive, heavily dependent upon synthetic chemicals and other off-farm inputs (Schaller, 1993). Sustainable agriculture refers to the ability of a farm to produce perpetually. Among other requirements, this means that any outside inputs employed for agriculture must be available indefinitely, so non-renewable resources are avoided. As it pertains to agriculture, sustainable describes farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely. Such systems... must be resource-conserving, socially supportive, commercially competitive, and environmentally sound" (Ikerd, 1990).

On a regional or national level, it appears that more widespread adoption of sustainable agriculture can meet many of the government's stated policy objectives for agriculture. Studies done to date indicate that total net farm income would increase, government subsidy payments could decline, environmental damage would decline, food quality would improve, and rural employment possibilities rise. Potential problems that could develop include a decline in export of major commodities such as wheat (due to diversification of production), dislocations in the farm input supply sector, and a shortage of skilled labor, manure and sources of potassium (Ecological Agriculture Projects, 1989; Goldemberg 1987; Bender, 2001).

An additional demand is about to be placed on agriculture resources. According to De La Torre Ugarte et al, (2003), agriculture can supply 150.7 million dry tons of biomass from traditional cropped land to support a renewable energy sector. This will require up to 42 million acres of land. In his 2006 State of the Union Address, President Bush remarked that “We’re working on research—strong research to figure out cellulosic ethanol that can be made from wood chips or stalks or switchgrass” (Zunes, 2006). The Energy Act of 2005 provides incentives with an objective of moving the nation towards ethanol by establishing a renewable fuel standard and offering additional research and development funds and investment incentives (Farrell et al, 2006).

Biomass

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Its advantage is that it can be used to generate electricity with the same equipment or power plants that are now burning fossil fuels. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas.

In 2003, biomass was the leading source of renewable energy in the United States, providing 2.9 Quadrillion Btu of energy. Biomass was the source for 47% of all renewable energy or 4% of the total energy produced in the United States (US

Department of Energy). Agriculture and forestry residues, and in particular residues from paper mills, are the most common biomass resources used for generating electricity, and industrial process heat and steam and for a variety of biobased products. These are the organic byproducts of food, fiber, and forest production. Current biomass consumption in the United States is dominated by industrial use, largely derived from wood. Use of liquid transportation fuels such as ethanol and biodiesel, however, currently derived primarily from agricultural crops, is increasing dramatically. In 2003, ethanol produced from corn reached 2.81 billion gallons (US Department of Energy).

Ethanol and biodiesel, made from plant matter instead of petroleum, can be blended with or directly substitute for gasoline and diesel, respectively. Use of biofuels reduces toxic air emissions, greenhouse gas buildup, and dependence on imported oil, while supporting agriculture and the nation's rural economies. Unlike gasoline and diesel, biofuels contain oxygen. Adding biofuels to petroleum products allows the fuel to combust more completely and this reduces air pollution. When fossil fuels such as petroleum are burned, they also release carbon dioxide that was captured by plants billions of years ago. This release contributes to the buildup of greenhouse gases that contributes to climate change. On the other hand, carbon dioxide released from burning biofuels is balanced by the carbon dioxide capture by the recent growth of the plant materials from which they are made. Depending on how much fossil energy is used to grow and process the biomass feedstock, this results in substantially reduced net greenhouse gas emissions. Biobased products that provide equivalents or alternatives to those made from petroleum and natural gas also contributes to oil import and greenhouse

gas reduction, while enhancing biorefinery economics (Union of Concerned Scientists, 2005).

Many farmers already produce biomass energy by growing corn to make ethanol. But biomass energy comes in many forms. Virtually all plants and organic wastes can be used to produce heat, power, or fuel. Biomass energy has the potential to supply a significant portion of America's energy needs, while revitalizing rural economies, increasing energy independence, and reducing pollution. Farmers would gain a valuable new outlet for their products. Rural communities could become entirely self-sufficient when it comes to energy, using locally grown crops and residues to fuel cars and tractors and to heat and power homes and buildings (Union of Concerned Scientists, 2005).

Crops grown for energy could be produced in large quantities, just as food crops are. While corn is currently the most widely used energy crop, native trees and grasses are likely to become the most popular in the future. These perennial crops require less maintenance and fewer inputs than do annual row crops, so they are cheaper and more sustainable and require less energy to produce.

A joint study with The University of Tennessee, Oak Ridge National Laboratory (ORNL), and the USDA found that farmers could grow 188 million dry tons of switchgrass on 42 million acres of cropland in the United States at a price of less than \$50 per dry ton delivered. This level of production would increase total U.S. net farm income by nearly \$6 billion. ORNL also estimates that about 150 million dry tons of corn stover and wheat straw are available annually in the United States at the same price, which could increase farm income by another \$2 billion. This assumes about 40 percent of the total residue is collected and the rest is left to maintain soil quality.

Switchgrass as Biomass Feedstock

Switchgrass is a potential feedstock source for producing bioenergy. Switchgrass is a perennial grass that is native to North America and can be managed using common agricultural practices. Using switchgrass as a energy feedstock to produce electricity generates fewer atmospheric emissions, especially sulfur. Switchgrass also adds organic matter to soils and can help reduce erosion on highly erodible lands. Furthermore, switchgrass can provide valuable habitat for wildlife (McLaughlin, et al., 1999).

Switchgrass production can benefit farmers, taxpayers, industrial-fiber producers, energy producers and consumers of energy. Bioenergy can be produced by co-firing switchgrass with coal to produce electricity in existing power plants offers a near term energy production alternative, as does eventually using switchgrass as a feedstock in bio-reactors that produce bio-based fuels or industrially important chemicals (Burden, 2003).

There are several environmental benefits to switchgrass production for biomass. It can be established on a multitude of landscaped soils and maintained as a renewable resource. With respect to energy production, switchgrass as a crop sequesters carbon, therefore reducing atmospheric carbon-dioxide content.

Switchgrass in Tennessee

The use of switchgrass for energy production is still in the experimental stages and as a result the market for switchgrass is not developed. Assessing the feasibility of switchgrass production for energy generation will require the collection of information on both the supply and demand side.

Research by two economists with the University of Tennessee, Daniel G. De La Torre Ugarte and Burton C. English, indicates that the Mid South, in particular Tennessee, could play a huge role in meeting federally established renewable energy goals through the production of dedicated energy crops such as switchgrass (McDaniels, 2006). A study by the University of Tennessee Agricultural Policy Analysis Center suggests that switchgrass could have been a moneymaker for farmers between 1996 and 2000, years during which commodity prices were low. The study indicates that if switchgrass had competed with major crops for acreage during that period about 22 million acres may have been converted to switchgrass production, because profits for the raw commodity priced at \$40 per dry ton exceeded those of the major commodities like corn and soybeans in many regions of the US (De La Torre Ugarte et al, 2003).

Objectives of the Study

Understanding the factors affecting a farmer's decision to adopt a new crop is essential in developing strategies to commercialize various new crops that may benefit the economy.

The objectives of this study is to investigate the factors that might influence an individual producers' choice to grow switchgrass and to develop a model to test whether farmers who are unsure about growing switchgrass have a propensity to choose to grow switchgrass if given more information.

Given the above objectives of the research, the study attempted to explore the following research questions:

1. What socio-economic characteristics are associated with Tennessee farmers' interest in growing switchgrass?
2. What is the likely adoption rate of switchgrass by Tennessee farmers who answered 'Do not know, but would like more information' regarding interest in growing switchgrass if profitable?

Literature Review

Adoption-Diffusion Theory

Perhaps the earliest and most frequently cited study on switchgrass adoption is that of Hippie and Duffy who used the adoption-diffusion theory to guide switchgrass adoption research. Adoption and diffusion of innovations theory (Rogers, 1995) has been widely used to identify factors that influence an individual's decision to adopt or reject an innovation. An innovation, according to Rogers, is 'an idea, practice, or object that is perceived as new by an individual or other unit of adoption.'

Rogers identifies five characteristics of an innovation that affect an individual's adoption decision. These are (1) relative advantage, which is the degree to which an innovation is perceived as being better than the idea it supersedes; (2) compatibility, or the degree to which an innovation is perceived as consistent with the existing values and beliefs, past experiences, and the needs of potential adopters; (3) complexity, which is the degree to which an innovation is perceived as relatively difficult to understand and use; (4) trialability, or the degree to which an innovation may be used experimentally on a limited basis; and (5) observability, which is the degree to which the results of an innovation are visible to others (Boz and Akbay, 2004).

Classical adoption-diffusion theory has been criticized for pro-innovation bias, individual-blame bias, and issues of equality. In the beginning, adoption-diffusion researchers identified characteristics of adopters, such as socio-economic status, personality, communication behavior, and risk tolerance that determine the likelihood of adoption. More recently, the focus of adoption-diffusion research has been on attributes of innovations and rates of adoption. Such attributes include relative advantage (economic factors, status aspects, effects of incentives); compatibility (with needs, values and beliefs, previously introduced ideas, and technology clusters); complexity; trialability; observability; diffusion affect; and, over adoption (Hippie & Duffy 2002). The relative advantage and observability of an innovation describe the immediate and long-term economic benefits (i.e., profits) from using it, whereas compatibility, complexity, and trialability indicate the ease with which a potential adopter can learn about and use an innovation (King and Rollins, 1995; Boz and Akbay, 2004).

The Logit Model

Adoption studies in agriculture generally attempt to establish factors that influence adoption of a technology in a specific locality. It is recognized that attributes influencing the adoption of agricultural technologies are inherent in the farmer and farm, in the technology itself, and the farmer's objectives (Adesina and Zinnah, 1993).

Discrete choice (mathematical or econometric) models, in particular the logit, probit, tobit, and multinomial logit models, have been widely used to determine the composition of explanatory variables (predictors) influencing the adoption process of new technologies by farmers. Literature suggests that the farm, the farmer, and institutional

factors drive farmers to adopt new technologies (Feder, 1980; Just, and Zilberman, 1983). Factors such as the financial and socio-economic impacts of new technologies, effects of new technologies in the risk of the farm, available resources, and technology transfer programs also have an effect on the decision of the farmer to adopt new technologies (Nell, 1998).

To analyze farmer adoption rates many authors have used a qualitative (binary) dependent variable (Nell, 1998; Gujarati, 1988). Binary functions cannot be estimated through the ordinary least squares method, since the predicted values from the resultant linear probability model cannot be constrained to the required interval without imposing restrictions on the values of independent variables. Binary methods can be estimated through maximum likelihood methods. The logit model postulates that the probability of a farmer (P) choosing to adopt is a function of some characteristic (X_i). These characteristics may be socioeconomic, institutional, or geographical. The model uses a logistic curve to transform binary responses into probabilities within the 0-1 interval. The logit model is specified as:

$$P_i = 1/(1+\exp(\beta_1 X_i))$$

Where P_i is the probability of adoption, X_i are farmer's characteristics, and β_1 is the corresponding regression coefficient (Davidson and Madkinno, 1995).

Henry, Klakhaeng, and Gottert (1995) used a logit regression model, following the methods of Hosmer and Lemeshow (1989) to overcome the limitations of the traditional ordinary least squares regression model. This was done to include the estimation of relationships that include dichotomous dependent variables (adoption vs. non-adoption) (Gujarati, 1998; Nell, 1998). Grisely and Shamambo (1990) also used a

logit model to predict the adoption rate of a bean cultivar. They used tabular and linear correlation methods to identify characteristics of the households and farms studied and the extent of adoption diffusion.

Empirical Studies on Adoption

The early empirical studies of the dynamics of diffusion in agriculture conducted in the United States during the 1940s and 1950s established some of the basic notions regarding adoption behavior over time. Studies conducted by rural sociologists have documented sigmoid diffusion curves over time for several agricultural innovations (Rogers 1957). Many of these studies have focused on the role of communications in determining the pace of the diffusion process and the shape of the diffusion curve. For example, Rogers empirically discusses the existence of different stages of the adoption process for different categories of adopters of hybrid corn in the United States. He found that the awareness gap and the experimentation period are shorter for the early adopters than for followers (Feder et al, 1985).

Much of the current research on technology adoption moves beyond the awareness stage and focuses on the long-term extent of adoption, rate of adoption, and the factors that influence the adoption decision (Feder et al., 1985; Daberkow and McBride, 2003). While there is a broad agreement that profitability plays a key role in the extent and rate of technology adoption, most studies acknowledge that heterogeneity among farmers can often explain why not all farmers adopt an innovation in the short or long run (Batte and Johnson, 1993; Khanna and Zilberman, 1997; Daberkow and McBride, 2003). For example, Rogers (1995) hypothesized that innovators or early

adopters have attributes different from late adopters or those that never adopt the technology. Feder and Umali (1993) make a distinction between adoption factors during the early phases of adoption versus the final stages of adoption. In other cases the nature of the technology or the financial, location, size, and physical attributes of the farm may influence the adoption decision (Daberkow and McBride, 2003).

Among Rogers' generalizations, educational level, farm size, and income have been found as significant variables that affect adoption in many studies. Ryan and Gross (1943) in their study on the diffusion of hybrid corn in Iowa assigned farmers to adopter categories on the basis of when they adopted the new seed. They found that the innovators, as compared to later adopters, had larger-sized farms, higher incomes, and more years of formal education. Innovators were also more cosmopolitan than later adopters. In their study on the adoption of irrigation by Ohio farmers, Rogers and Pitzer (1960) found that adopters had more years of formal education, larger-sized farms, and more contacts with extension personnel. Brander and Kearn (1964) in their study on the adoption of hybrid sorghum among Kansas's farmers found that adopters were younger, had more years of formal education, and operated more acres than non-adopters. Norris and Batie (1987) analyzed Virginia farmers' soil conservation decisions and found that farmers who spend more money on soil conservation practices had larger-sized farms, higher incomes, and lower levels of debts (Boz and Akbay, 2004).

Duffy and Hippie (2002) found, that before making the adoption decision, potential adopters want to know actual or anticipated: costs per acre; labor involved; equipment requirements; other capital requirements; fertilizer needs; land best suited for

production; expected return on investment; market identification and stability; and cost-benefit comparison between switchgrass, conventional row crops, and other alternatives.

Research Methodology

Description of the Study Area

Production and Sales of Main Commodities

Tennessee agriculture is a complex and varied industry that benefits Tennesseans as well as many people outside the boundaries of the state. Tennessee's top agricultural commodities include cattle and calves, broilers, hardwood lumber, nursery and floriculture products, soybeans, cotton, dairy products, corn, tobacco, fruits and vegetables, wheat, hay, and hogs. Agricultural production alone, excluding forest products, typically generates \$2 billion annually in farm cash receipts (Tennessee Department of Agriculture, 2003). With approximately 50 % from livestock sale, cattle comprise of twenty percent of Tennessee's total cash receipts, while broilers comprise of seventeen percent of the state's total cash receipts.

Tennessee agriculture production is usually divided into three regions: East, Middle, and West. East Tennessee production consists of beef cattle, dairy farms, tobacco and vegetables. The abundant rolling pasture lands of Middle Tennessee make beef cattle and dairy operations practical choices for the region. A variety of row crops also flourish in Middle Tennessee. West Tennessee is a region of lush flatland created by the Mississippi River's ancient flood plains. This region's agriculture centers around row crop operations and the state's largest production of soybeans, wheat, corn, cotton and sorghum (Tennessee Department of Agriculture, 2003).

General Characteristics

Almost 95 percent of Tennessee farms are family or individually owned (Table 16). The average farm size for all farms in the state is 133 acres with an average of 50 acres in harvested cropland. For all farms in the state, 11.6 million acres are farmed with land enrolled in the Conservation Reserve Program. Approximately 50 percent of the farmer's primary occupation is farming with 83 percent having a residence on a farm they operate. Twenty-two percent of Tennessee farms have sales greater than \$10,000. The average age of farmers is 56 years (Table 17).

Sampling Procedure, Data Collection, and Analysis

Survey Methods

A mail survey of Tennessee Farmer's views on switchgrass production for energy was conducted in March and April of 2005 to examine whether farmers are willing to adopt switchgrass as a new crop. The field survey sampled farmers in all counties of Tennessee. These farmers were chosen on the basis of income from agricultural commodities grown. A total of 15,002 farmers with cash receipts greater than \$10,000 were contacted by a mail survey consisting of 27 questions. Following the survey procedures outlined by Dillman, a questionnaire was developed to query Tennessee farmers in all counties about their ability, attitudes, and willingness to adopt switchgrass as a new crop used for energy, as well as their demographic information.

The questions addressed four major areas: 1) the knowledge and interest of switchgrass as an energy crop; 2) the characteristics of the farm operation, including

Table 16. Characteristics of Tennessee farmers and farm operators.

	All Farms	Farms with sales > \$10,000
Number of Farmers	87,595	19,784
Farm Characteristics:		
Total Land Farmed (1,000 Acres)	11,682	6,665
Proportion of Farms with Land in CRP	0.05	0.03
Total Land in CRP (Acres)	227,996	46,663
Average farm size (Acres)		
All Farm Uses	133	338
Total Cropland	80	233
Harvested Cropland	50	173
Pastureland	22	51
Woodland	27	45
Other Land in farms	4	9
Land Tenure		
Proportion of Farms Renting Land	0.27	0.50
Average Amount of Land Rented (Acres)	158	297
Proportion of Farms Owning Land	0.96	0.94
Average Amount of Land Owned (Acres)	101	212
Proportion Partnership	0.05	0.09
Number of Partnerships	3,996	1,863
Proportion Sole Proprietor or Family Owned	0.95	0.88
Number of Sole Proprietor or Family Owned	82,866	17,443
Proportion of Farmers with Hay Balers	0.35	0.50
Farmer Characteristics:		
Average Age (Years)	56.0	55.9
Proportion Using Computer in Farm Business	0.27	0.34
Proportion With Internet Access	0.41	0.43
Proportion With Primary Occupation as Farming	0.50	0.67
Proportion With On-Farm Residence	0.83	0.83

Source: USDA, National Agricultural Statistics Service, 2002 Census of Agriculture, Table 56

Table 17.Characteristics of survey respondents and statewide census.

Characteristic	Survey Respondents	Tennessee State Farmers
Net Farm Income After Taxes		
Negative (Less than \$0)	15.42%	Average is \$11,331
\$0 - \$9,999	49.32%	
\$10,000 - \$ 14,999	14.39%	
\$15,000 - 24,999	9.96%	
\$25,000 - \$34,999	4.80%	
\$35,000 - \$ 49,999	2.60%	
\$50,000 - \$74,999	1.73%	
\$75,000 - \$99,999	0.80%	
\$100,000 - \$149,999	0.53%	
Greater than or equal to \$150,000	0.47%	
Education Level Obtained:		
Some High School of Less	12.44%	24.10%
High School Graduate	38.12%	31.60%
Some College	19.89%	24.80%
College Graduate	16.40%	19.60%
Post Graduate	13.15%	
Age:		
15 years to 44 years	11.32%	45.21%
45 to 64 years	50.46%	34.29%
65 or older	38.22%	20.50%
Sources: Economic Research Service, USDA		

types of enterprises and use of various agricultural practices; 3) farm income; and 4) socio-demographic characteristics of the farmers. This report provides results aggregated over all counties in Tennessee.

The questionnaire, a postage-paid return envelope, and a cover letter explaining the purpose of the survey were sent to select Tennessee farmers. The initial mailing of the survey was in Mid-March and a reminder postcard was sent one week later. A follow-up mailing to farmers not responding to the first inquiry was conducted 3 weeks later. The second mailing included a letter indicating the importance of the survey, the questionnaire, and a postage-paid return envelope. The survey contained statements about individual responses being confidential and the responses voluntary. All surveys were sent by the contracted survey company named TASS (Tennessee Agricultural Statistics Service), therefore no names or addresses were available to the principle investigators. All survey information is stored in a secure area and will be destroyed within 3 years of the completed project.

Factors affecting the decision of respondents who chose ‘don’t know, but would be interested in obtaining more information’ to be interested in switchgrass if given more information were identified using the binary logistic regression analysis from SPSS 13.0 for Windows. The study sample contains 3,478 Tennessee farmers with at least \$10,000 in sales of agricultural products. Among these sampled, 46.70% chose ‘do not know, but would like more information’. Of the ‘do not know’ respondents, about 34.47% were in the group that chose to grow switchgrass and about 65.53% were in the group that chose to not grow switchgrass. Table 17 presents descriptive statistics for the study sample.

Non-Response Analysis and Data Analysis

Of the 15,002 surveys mailed, 282 were returned undeliverable, 90 were returned by addressee for reasons other than the addressee was no longer capable of farming, and 102 were returned because addressee was no longer capable of farming. Of the remaining 14,720 received surveys, data were obtained from 3,499 units for a response rate of 23.79%. While socio-economic data were not available for non-respondents, information about location was available. Chi-Squared tests were used to evaluate the association between urban/rural county and response and also region within the state response. No significant degree of association was found between either of these locations variables and response, suggesting no geographically related non-response bias.

In comparing statistics from respondents with state statistics, it appears that the respondents were older than the state population. The most common Net Farm Income after Taxes category among the respondents was \$0 - \$9,999 (representing 49.32% of the respondents). A smaller percent of respondents held college degrees in the state overall. The data analysis was carried out using the SPSS version 13 software packages.

Conceptual Framework

Analytical Model

For this study, a model that reflects the observed status of deciding to grow switchgrass if profitable was required. Such observations reflect a dichotomous variable, adopting or not adopting. Generally, three types of models can be used to measure binary response behavior: linear probability model, the logit model and the probit model.

The linear model should not be used for this type of analysis since the dependent variable is not constrained between 0 and 1 (Anemiya, 1981). The binary decision generates a non-linear response which violates the assumptions of the linear regression model. Therefore, a probability model based on cumulative frequency distribution is used.

The probability functions used for the probit and logit models are based on the normal distribution and on the logistic distribution functions respectively and they are bounded between 0 and 1 and they exhibit a Sigmoid curve, conforming to the theory of adoption (Sheikh et al, 1999).

The logit and probit models are quite similar as the cumulative normal and logistic distributions are very close to each other except at their tails. However, the tails of the logistic model are flatter than the probit model (Sheikh et al, 1999). The results produced by either model are similar, unless the samples are very large and many observations fall near the tails (Maddala, 1983). Unless there are other theoretical reasons for preferring a distribution function to the logistic cumulative distribution function, the logit model is preferred when repeated observations are available (Judge et al, 1980; Sheikh et al, 1999). The logistic model also has a direct interpretation in terms of the logarithm of the odds in favor of success. Being based on the cumulative logistic probability function, the logit model can be used for transforming the dependent variable to predict probabilities within the bound (0, 1). The dependent variable becomes the natural logarithm of the odds when a positive choice is made.

The Binary Logit Forecast Model

This study attempts to determine the probability a surveyed farmer who responded ‘don’t know’ to growing switchgrass would choose to grow switchgrass if given more information. This study also attempts to determine a relationship between the choice and certain attributes of the surveyed farmers. In the analysis, surveyed farmers who indicated ‘yes’, would be interested in growing switchgrass’ were treated as potential growers while those who responded ‘no’, would not be interested in growing switchgrass’ were treated as definite non-growers. Surveyed farmers responding ‘don’t know, but would be interested in obtaining more information’ were undecided at the time of the survey.

The econometric probability model assumes that an unobserved underlying response is defined by the regression relationship (Maddala, 1992). In the following equation, (1), Y_i is not observed and would be defined as the tendency to be interested in growing switchgrass.

$$Y_i = \beta_o + \sum \beta_i X_i + u \quad (\text{eq.1})$$

Where β_o is the intercept.

X_i is the explanatory variable.

β_i is coefficient of each X_i explanatory variable, and

u is error term which is assumed that is symmetrically distributed with zero mean and a cumulative distribution function defined as $F(u)$.

Y is a binary variable that represents the decision to be interested in growing switchgrass. The observed variable serves as a proxy for the unobservable dependent variable: Y is set to one if they are interested in growing switchgrass and equal to zero if they are not interested in growing switchgrass.

$$Y = 1 \text{ if } Y_i > 0$$

$$Y = 0 \text{ other wise} \quad (\text{eq.2})$$

From equation (1) and (2), the following probability model can be obtained assuming that variable (u) is equal to 1 (Maddala, 1983).

$$\begin{aligned} P &= \text{Prob}(Y=1) = \text{Prob}[u > -(\beta_o + \sum \beta_i X_i)] \\ &= 1 - F[-(\beta_o + \sum \beta_i X_i)] \end{aligned} \quad (\text{eq.3})$$

Where P is the probability of being interested in growing switchgrass, and

F is the cumulative distribution function of u.

The cumulative distribution function of a random variable X, denoted by $F_x(x)$, is defined by $F_x(x) = P_x(X \leq x)$, for all x (Kim and Geistfeld, 2004). Thus, the distribution of u is symmetric and equation (3) can be written as the following:

$$P_x = \text{Prob}(y=1) = F_x(\beta_o + \sum \beta_i X_i) \quad (\text{eq.4})$$

In equation 4, the parameter β_i relates to the changes in the probability of choosing to be interested in switchgrass resulting from the explanatory variable X_i (Kim and Geistfeld, 2004). The value of β_i represents the relative strength of the effect and the sign of β_i indicates the direction of the relationship between the explanatory variable and the probability of being interested in growing switchgrass.

The functional form of F depends on the nature of the distribution of u in equation (1). If the logistic distribution of u is assumed, the logistic expression is:

$$F(Z_i) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] \quad \text{Or} \quad (\text{eq.5})$$

$$\log \left[\frac{F(Z_i)}{1 - F(Z_i)} \right] = Z_i \quad (\text{eq.6})$$

$$\text{Where } Z_i = \beta_o + \sum \beta_i X_i$$

Based on equation (4) and (6), the following equation can be derived:

$$\log \left[\frac{\Pr(y = 1)}{1 - \Pr(y = 1)} \right] \beta_o + \sum \beta_i X_i \quad (\text{eq.7})$$

Equation (7) represents the logit model for a binary outcome in terms of ratio of the probability of being interested in growing switchgrass to the probability that the surveyed farmers will not be interested in growing switchgrass. This ratio is called the odds ratio and the left –hand side of the equation is called the log-odds (Kim and

Geistfeld, 2004). Using natural logarithm of the odds as a dependent variable solves the problem that the estimated probability may exceed the maximum or minimum possible values (Menard, 1995). In this model, logistic coefficients can be interpreted as the change in the log-odds associated with a one-unit change in the independent variable when other things are equal.

The logit model, expressed in equation 8, can also be represented as an event probability based on equations (4) and (5).

$$\Pr(Y = 1) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] \quad (\text{eq. 8})$$

$$\Pr(Y = 0) = \left[\frac{\exp(-Z_i)}{1 + \exp(-Z_i)} \right] = \left[\frac{1}{1 + \exp(Z_i)} \right]$$

$$\text{Where } Z_i = \beta_0 + \sum \beta_i X_i$$

The logit model can be expressed in two forms: in terms of the logit and in terms of event probability (Kim and Geistfeld, 2004). These two different forms are, however, based on the same underlying framework (Liao, 1994).

Interpretation of Variables

For the meaningful interpretation, the regression model must first fit the data and the model must be able to explain the response outcome significantly better than the

model with the intercept only (DeMaris, 1992; Liao, 1994). The likelihood ratio test based on Maximum Likelihood Estimation Method (MLE) is the most commonly used large-sample test in probability models (Kim and Geitsfeld, 1994; Maddala, 1992). Maximum likelihood parameter estimation determines the parameters that maximize the probability (likelihood) of the sample data. From a statistical point of view, the method of maximum likelihood is considered to be more robust (with some exceptions) and yields estimators with good statistical properties. MLE methods are versatile and apply to most models and to different types of data. In addition, they provide efficient methods for quantifying uncertainty through confidence bounds. The likelihood ratio statistic tests the null hypothesis that all regression coefficients in the full model are 0 except the intercept. Rejecting the null hypothesis implies that the full model fits the data significantly better than the model with the intercept only.

In general, the likelihood ratio tests consists of using $-2 \log$ likelihood instead of the log likelihood itself because the $-2 \log$ likelihood approximately follows the Chi-squared distribution with degree of freedom equal to the number of parameters in the model (Menard, 1995). The likelihood ratio statistic (C) can be computed by taking the negative of twice the natural logarithm of the ratio of the two likelihood values.

$$C = -2 \log (L_0/L_1) = (-2 \log L_0) - (-2 \log L_1) \quad (\text{eq. 9})$$

Where L_0 is the maximum value of the likelihood function when all coefficients except the constant are 0 and

L_1 is the maximum value of the likelihood function for the full model.

Binary logistic regression analysis gives the -2 log likelihood for both full model and the model with an intercept only through the iteration history. MLE is an iterative algorithm which starts with an initial arbitrary "guesstimate" of what the logit coefficients should be, the MLE algorithm determines the direction and size change in the logit coefficients which will increase LL. After this initial function is estimated, the residuals are tested and a re-estimate is made with an improved function and the process is repeated (usually about a half-dozen times) until convergence is reached.

Significant Test for a Coefficient

The interpretation of a logistic regression coefficient, β , is not as straightforward as that of a linear regression coefficient. Hence, the coefficients are often converted into odds ratios by exponentiating the coefficient (Bergerud, 1996). For the significant test for each coefficient, the likelihood ratio and the Wald statistic are commonly used tests and both statistics are based on the Maximum Likelihood Estimation (Maddala, 1992). Binary logistic regression analysis in SPSS uses the Wald statistic for the significant test for each coefficient. For a categorical variable, each category had a single degree of freedom. When a variable has a single degree of freedom, the Wald statistic, which follows approximately a Chi-square distribution, can be computed by taking the square of the ratio of the coefficient to its standard error (Kim and Geistfeld, 2004).

The Marginal Effect of Log Odds

The logistic coefficients represent the change in the logit of an event occurring corresponding to a change of one unit in the independent variable, controlling for all other independent variables (Kim and Giestfeld, 2004). In interpreting the logistic

coefficient in terms of the effect on the logit, the threshold between negative and positive effects is 0 and the effects on the logit are linear and additive as the coefficient in ordinary least square regression.

The Marginal Effects on Odds

Interpreting the results in terms of the effect on odds comes from transforming the logistic coefficients so that the independent variables affect the odds rather than the logit. In equation (7), exponentiation both sides of the logistic equation provides the effects of the independent variables on the odds.

$$\exp \left[\log \frac{\Pr(y = 1)}{1 - \Pr(y = 1)} \right] = \exp(\beta_0 + \sum \beta_i X_i)$$

$$Odds = \left[\frac{\Pr(y = 1)}{1 - \Pr(y = 1)} \right] = \exp(\beta_0) * \exp(\sum \beta_i X_i) \quad (\text{eq. 10})$$

In equation 10, the exponential coefficient is called an odds ratio and represents a multiplicative change in the odds rather than an additive change. In interpreting odds ratio, the threshold between negative and positive effects is 1 instead of 0 and an odds ratio of 1 corresponds to the logistic coefficient of 0 (Kim and Giestfeld, 2004). The distance of an exponential coefficient from 1 in either direction indicates the size of the effect on the odds for a one-unit change in the independent variable. Therefore the

percentage change in odds is expressed as the following equation (DeMaris, 1992; Pampel, 2000).

$$\text{The percentage change in odds} = [\exp(\beta_i) - 1] * 100 \quad (\text{eq.11})$$

The Marginal Effect on Probabilities

Based on the coefficients, predicted probability for a given set of values of the independent variables can be computed. Equation 8 estimates the predicted probability of an event occurring.

The probability is a function of the values of all explanatory variables in the model and each independent variable has a different effect on the probability depending on its level and the level of the other independent variables. Therefore, the relationship between the independent variables and the probability are nonlinear and nonadditive (Liao, 1994; Kim and Geistfeld, 2004). It is not possible to represent the marginal effect of a given predictor on the probability for all cases using a single coefficient. Therefore, interpreting the logistic coefficients in terms of the marginal effect on the probability is useful to examine a typical case. It is useful to examine the probability focusing on one or two variables and setting the values of other variables at their sample means (Liao, 1994).

For a continuous independent variable, computing the event probability before and after a unit change in the explanatory variable provides the marginal effect of the explanatory variable on the probability (Kim and Geistfeld, 2004).

For a continuous independent variable, there is another way to compute the marginal effect of an independent variable on the probability of choosing to grow

switchgrass. The slope of the tangent line of logistic curve at a particular point represents the linear change in the probability for one-unit change in the independent variable (Pampel, 2000; Kim and Geistfeld, 2004). Equation 11 shows that the partial derivative is computed by multiplying the logistic coefficient by the probability at a single point and 1 minus the probability. According to the equation, the marginal effect is maximized when the probability is .5.

$$\begin{aligned} \partial P / \partial X_i &= \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] * \left[\frac{1}{1 + \exp(Z_i)} \right] \beta_i \quad (\text{eq.12}) \\ &= P (1-P) * \beta_i \end{aligned}$$

For a categorical independent variable, equation 12 has less meaning because the relevant changes that define the tangent imply the difference between membership in the indicator category and membership in the omitted category. Thus, for a categorical variable it is better to computer the probability for each group and measure group differences in probability (Petersen, 1985).

Variables Included in the Model and Their Hypothesized Effect

The measure of adoption used in this study is the propensity of a farmer to choose to grow switchgrass by the indication of answering ‘Yes, I am interested’ on the related survey. Farmers were asked whether they were interested, or not interested, or did not know in growing switchgrass for energy if profitable. Adopters were defined as farmers who were interested in growing switchgrass. Therefore, the dependent variable represents the extent of adoption and it is a function of social, institutional, physical,

economic, and attitudinal factors. The definitions of the explanatory variables included in each factor category are presented in Table 18.

Formation of the model was influenced by a number of working hypothesis. Based on the literature reviewed it was hypothesized that a farmers' decision to adopt switchgrass is influenced by a combined effect of a number of factors related to the farmers and farm characteristics. Current farm land situation and farm business variables are controlled only by using provincial dummy variables.

The following are the independent variables:

- *Has heard of switchgrass* (dummy variable): knowledge of switchgrass is reported as having heard of switchgrass (1) or not having heard of switchgrass (0).
- *Owns hay equipment* (dummy variable): if farmers own hay equipment the value is (1), if they do not own hay equipment the value is (0).
- *Owns a personal computer* (dummy variable): if farmer owns a personal computer the value is (1), if they do not, the value is (0).
- *Currently belongs to a grower or commodity organization* (dummy variable): if the farmer belongs to this type of organization the value is (1), if they do not, the value is (0).
- *Currently belongs to a hunting related organization* (dummy variable): if the farmer belongs to this type of organization the value is (1), if they do not, the value is (0).

Table 18. Definition of variables.

Variables	Definition	Expected Sign
Dependent Variable		
Choose to Grow Switchgrass	Choose Not to Grow = 0 Choose to Grow = 1	NA
Independent Variables (Categorical)		
HHOS	Has heard of switchgrass = 1; 0 otherwise	+
OHAY	Owns hay equipment = 1; 0 otherwise	+
NOTILL	Currently uses no-till production methods = 1; 0 otherwise	+
OCOMP	Owns personal computer = 1; 0 otherwise	+
GROW	Currently belongs to a grower or commodity organization = 1; 0 otherwise	+
HUNT	Currently belongs to a hunting-related organization = 1; 0 otherwise	+
ENVIR	Currently belongs to an environmental organization = 1; 0 otherwise	+
FARM	Currently belongs to a Farm Bureau = 1; 0 otherwise	+
COOP	Currently belongs to a cooperative = 1; 0 otherwise	+
NIL75	Net income from farming in 2004 (after taxes) is less than \$75K = 1; 0 otherwise	+
Dummy for Farm Situation HCCP	Currently has a Conservation Compliance Program = 1; 0 otherwise	+ or -
Dummy for Farm Situation NCCP	Does not have a Conservation Compliance Program, but practice erosion control methods = 1; 0 otherwise	+ or -
Dummy for Farm Situation NERO	No significant erosion problem on farmland = 1; 0 otherwise	-
Dummy for Farm Situation EROS	Significant erosion control program, but erosion control practices are not used currently = 1; 0 otherwise	+ or -
Dummy for Farm Situation FSOTH	Other farm situation = 1; 0 otherwise	+ or -
Dummy for farm business FOWN	A full owner of farming business = 1; 0 otherwise	+
Dummy for farm business POWN	A part owner of farming business = 1; 0 otherwise	+ or -
Dummy for farm business RENT	A renter of farming business = 1; 0 otherwise	+ or -
Dummy for farm business LLC	A limited liability corporation farming business = 1; 0 otherwise	+ or -
Dummy for farm business FBCOOP	A cooperative farming business = 1; 0 otherwise	+ or -
Dummy for farm business FBOTH	Other farming business = 1; 0 otherwise	+ or -
EDCG	College graduate = 1; 0 otherwise	+
Independent Variables (Continuous)		
AGE	Age in years	+ or -
EXP	Years of farming experience	+ or -
HOAW	How often attends workshops	+
TACF	Total acres farmed	+

- *Currently belongs to an environmental organization* (dummy variable): if the farmer belongs to this type of organization the value is (1), if they do not, the value is (0).
- *Currently belongs to a farm bureau* (dummy variable): if the farmer belongs to this type of organization the value is (1), if they do not, the value is (0).
- *Currently belongs to a cooperative* (dummy variable): if the farmer belongs to this type of organization the value is (1), if they do not, the value is (0).
- *Net income from farming after taxes is less than 75K* (dummy variable): if the farmer makes less than 75K the value is (1), if they make more than 75K the value is (0).
- *Farms current situations* (5 dummy variables): these represent the current condition of farmland. The first dummy taking a value of one for farmers who currently have a conservation compliance program; the second being one for farmers who do not have a conservation compliance program, but practice erosion control methods; the third being one for farmers with no significant erosion problem on farmland; and the fourth being one for farmers with significant erosion control program, but erosion control practices are not used currently. The last dummy variable takes on a value of one for farmers who indicated more than one of the previous situations for farmland. The latter category is the reference category.

- *Farming business* (5 dummy variables): these describe the farming business expressed in 5 dummy variables, the first taking a value of one for full owner; the second taking the value of one for part owner in partnership, family held cooperation, or other cooperation; the third taking a value of one for a renter; the fourth taking a value of one for a limited liability cooperation; the fifth taking on a value of one for a cooperative; and the last taking a value of one for those whose farming business is in the other category. The latter category is the reference category.
- *Education* (dummy variable): if farmers were a college graduate the value is 1, else the value is (0).
- *Age of farmer* (continuous variable): is included to capture the time horizon of the farmer.
- *Experience of farmer* (continuous variable): is included to capture the time horizon of the farmer.
- *How often attends workshops* (continuous variable): is included to capture times per year the farmer attends extension workshops or experiment station field days.
- *Farm size* (continuous variable): is measured in acres.

Social Factors

Personal characteristics relate to an individual's management skills or entrepreneurial ability and include attributes such as level of education, farming experience, and any vocational training (Feder et al, 1985; Sheikh et al., 1999). They

reflect a farmer's ability to understand farm technologies and their effect on farming as farmers have different levels of management skills. The synthesis of the adoption process suggests that generally the level and quality of human capital affects the choice of new technologies in agriculture and for early adopters (Sheikh et al., 1999).

One study by Shortle and Miranowski found that personal characteristics affect the choice of conservation tillage practices. Similarly, a study by Ervin found that education has a positive impact on the adoption of soil conservation technology.

Studies have shown that age of the farmer is related to adoption decisions. They also found that older farmers are less likely to use soil conservation practices, whereas younger farmers may be better educated and involved with more innovative farming. Shortle and Miranowski found experience has a positive effect of the adoption of conservation tillage practices in the Four Mile Creek Watershed of eastern Iowa (Sheikh et al., 1999).

Personal characteristics like age, educational attainment, and farm experience were hypothesized to influence the decision to adopt switchgrass. The age of a farmer (AGE) can enhance or prevent the adoption of a new crop. With age, a farmer may get experience about his farm (Young and Shortle, 1984) and can react in favor of switchgrass adoption. On the contrary, some research indicates that older farmers are more likely to reject farm change (Gould et al, 1989). Thus, age is expected to have a positive or negative effect on the adoption of switchgrass.

Exposure to education (EDCG) will increase a farmers' management capacity and reflect better understanding of the benefits and constraints of adopting switchgrass. Education is hypothesized to increase the probability that a farmer will adopt switchgrass.

Physical Factors

Farm size is regarded as one of the most important determinants of the adoption of new technologies. Its relationship with adoption depends on fixed costs associated with an innovation, risk preferences, and the constraints on credit availability (Feder et al., 1985). As the influence of these factors varies in different areas over time, the relationship between adoption and farm size may vary. For small farmers the level of fixed costs is an impediment to adoption (Sheikh et al., 1999). Thus, it is hypothesized that the bigger the farm size, the greater the chances of farmers choosing to grow switchgrass.

Institutional and Socio-Economic Factors

Land ownership is widely believed to encourage adoption of technologies linked to land. While several empirical studies support this hypothesis, the results are not unanimous and the subject has been widely debated (e.g., Feder et al., 1985). For example, Bultena and Hoiberg (1983) find no support for the hypothesis that land tenure had a significant influence on adoption of conservation tillage. Land ownership is likely to influence adoption if the innovation requires investments tied to the land. Presumably, tenants are less likely to adopt these types of innovations because they perceive that the benefits of adoption will not necessarily accrue to them. If the tenure of a lease is short and a considerable investment is required to use any new technology, then the chances of its adoption by a tenant would be less as compared with an owner operator (Sheikh et al., 1999). The chances of owner operators choosing to grow switchgrass are expected to be

greater as compared with those of tenant farmers. The dummy variable for type of farming business gives a crude measure of the different types of farm ownership.

Higher levels of income imply the ability to purchase the new equipment and to bear the risk associated with adoption. A positive relationship between the probability of adoption and net income should be expected. Owning hay equipment is expected to increase the chances of a farmer growing switchgrass.

If a farmer takes advantage of educational opportunities offered and takes part in community institutions, he is likely to adopt new technologies (Janick and Klindt, 1995; Sheikh et al. 1999). However, the results of a study by Ahmad et al. (1991) show that extension had no significant effect on the adoption of semi-dwarf wheat varieties in the northern areas of Punjab. The frequency of a farmer's visits to an extension workshop is a variable in this study with an indeterminate hypothesized sign. Owning a computer is expected to have a positive relationship on the choice to grow switchgrass.

One of the benefits of growing switchgrass is that it prevents soil erosion due to canopy cover extensive root systems. Therefore, the chance of switchgrass adoption by a farmer who has erosion problems is expected to be greater than those farmers who do not have erosion problems. Switchgrass provides nesting and cover habitat for wildlife, reduces air emissions related to fossil fuels when used to replace coal in electricity production, and reduces chemical and sediment run-off when used as buffer strips. The dummy variable for current farmland situation gives a crude measurement of the different land environments. Farmers who are members of environmental and hunting organizations, farm bureau, cooperative, or a growers association are expected to have a

greater probability of growing switchgrass. The practice of no-till production methods are expected to increase the chance of growing switchgrass.

Results

Results of the Logistic Regression

The analysis contains three parts. First, results of the logistic regression are reported. The results are then used to examine the effects that each variable has on the probability of adoption. Finally the estimated model is used to determine the proportion of ‘don’t knows’ who would adopt switchgrass.

As seen in Table 19, the model gave 74% correct predictions of adopters and non-adopters. The classification of adopter’s verses non-adopters indicates that the model classified adopters (87.1%) better than non-adopters (49.9%).

Table 20 shows the results of the binary logistic regression analysis of the decision to grow switchgrass. First, the overall fit of the equation is examined. The Hosmer and Lemeshow Test equal a significance of .538 which indicates a good fit of the model. Another goodness-of-fit measure is the McFadden’s R^2 , which is obtained as $1 - LL_r/LL_u$, where LL_u and LL_r are values of the unrestricted and restricted log-likelihood functions. The estimated McFadden’s R^2 is 0.223, which indicates the model is a good fit. Seven explanatory variables were significant, at the 5% significance levels in explaining adoption decisions of farmers for switchgrass.

Table 19. Classification table for predicted model.

		Predicted		
		Is Interested in Switchgrass		Percentage Correct
Observed		No	Yes	
Is Interested in Switchgrass	No	174	175	49.9
	Yes	84	567	87.1
Overall Percentage				74.1

Table 20. Estimated coefficients of binary logit model.

Variables (N = 1000)	Coefficients	Standard Error	Wald	Sig.	Exp(B)
HHOS = 1	.099	.184	.287	.592	1.104
OHAY = 1	.286	.178	2.594	.107	1.331
NOTILL = 1	.701	.160	19.245	.000	2.017
OCOMP = 1	.699	.170	16.976	.000	2.013
GROW = 1	-.454	.333	1.862	.172	.635
HUNT = 1	.265	.273	.944	.331	1.304
ENVIR = 1	1.161	.419	7.678	.006	3.194
FARM = 1	.318	.181	3.079	.079	1.375
COOP = 1	-.021	.160	.017	.896	.979
NIL75 = 1	-.544	.728	.557	.455	.581
HCCP = 1	-.331	.352	.888	.346	.718
NCCP = 1	-.416	.308	1.826	.177	.660
NERO = 1	-.837	.297	7.932	.005	.433
EROS = 1	.468	.504	.864	.353	1.597
FSOTH = 1	0**	-	-	-	-
FOWN = 1	-.063	.427	.022	.882	.939
POWN = 1	.022	.471	.002	.963	1.022
RENT = 1	-.423	.751	.317	.573	.655
LLC = 1	-1.672	1.142	2.142	.143	.188
FBOTH = 1	0**	-	-	-	-
EDCG = 1	-.230	.225	1.045	.307	.794
AGE	-.043	.008	27.825	.000	.958
EXP	-.003	.005	.317	.574	.997
HOAW	.204	.078	6.828	.009	1.226
TACF	.001	.001	6.414	.011	1.001
CONSTAN T	2.950	1.052	7.864	.005	19.109

Total acres farmed (TACF) is significant and is positively related to switchgrass adoption. This suggests that farmers with larger sized farms are more likely to adopt switchgrass as a new crop. How often the farmer attends workshops (HOAW) is significant and positively related to adoption. This suggests that farmers with contact to research-development or extension agencies have a greater likelihood of adoption switchgrass. Farmer age (AGE) is negatively related to switchgrass adoption suggesting that older farmers have a lower probability of adoption switchgrass as a new crop. No erosion problem on farmland (NERO) is negatively related to adoption suggesting that the likelihood of farmers adopting switchgrass will increase as the perceived level of erosion on farmland increases. Owning a computer (OCOMP), using no-till production methods (NOTILL) and belonging to an environmental organization (ENVIR) have positive relationships with switchgrass adoption supporting the hypothesis.

From table 20, the coefficient for the variable has heard of switchgrass is .099, and its standard error is .184. The Wald statistic is .287. Based on the Wald statistic, total acres farmed, no erosion problem, use of no-till production methods, age, how often attends workshops, and belongs to an environmental organization are significant factors affecting the decision to grow switchgrass at the .05 significance level.

The coefficient for the variable “how often attends workshops”, .204, indicates that when a farmers increases workshop attendance by one time, the logit of choosing to grow switchgrass increases by .204 (See Table 20).

For categorical independent variables, a unit change in the variable implies the difference between membership in the indicator category and membership in the omitted category (DeMaris, 1995, Pampel, 2000). The coefficient for the variable “those who

have no erosion problem”, -0.837, represents the logit for the group decreases by .837 compared with the logit for the omitted group, those with farm situations that have no perceived erosion problem.

From Table 20, the exponential coefficient for the variable “how often attends workshops”, 1.226, says the odds of choosing to grow switchgrass increase by 22.6% when attendance of workshops increases by 1.

To find the marginal effect on the probability when attendance at workshops increases from 2 to 3, the values in other variables were set to their mean and categorical variables were omitted. If the values of the categorical variables are set at the omitted category, all categories of the variable is coded as 0. In equation 8, the original equation for Z_i is the following:

$$Z_i = 2.950 + (.701)*NOTILL + (.699)*OCOMP + (1.161)*ENVIR + (-.837)*NERO + (-.043)*AGE + (.204)*HOAW + (.001)*TACF$$

Afterward, all categorical variables are set at their omitted group:

$$Z_i = 2.950 + (.701)*0 + (.699)*0 + (1.161)*0 + (-.837)*0 + (-.043)*AGE + (.204)*HOAW + (.001)*TACF$$

Then, setting HOAW to 2 and to 3 given all other variables are equal to their mean and reference categories we find the following:

Z_i (HOAW=2 | all other variables = means and reference categories)

$$= 2.950 + (-.043)*(58.29) + (.204)*(2) + (.001)*188.95$$

$$= 1.0401$$

$$\Pr(Y = 1) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] = .7389 = 73.89 \%$$

Z_i (HOAW=3| all other variables = means and reference categories)

$$= 2.950 + (-.043)*(58.29) + (.204)*(3) + (.001)*188.95$$

$$= 1.2445$$

$$\Pr(Y = 1) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] = .7763 = 77.63 \%$$

When attendance of workshops increases from 2 to 3, the probability that the respondent will choose to grow switchgrass increases 3.74%. The marginal effect on the probability depends on a given set of values of the independent variables and it is not a constant. Therefore, the marginal effect on the probability will not be the same when workshop attendance increases from 3 to 4.

In the previous calculation, the probability of choosing to grow switchgrass was 73.89% when workshop attendance was set at 2; the logistic coefficient for workshop attendance was .204. Equation 12 yields .0394 implying that one increase in workshop attendance increases the probability of choosing to grow switchgrass by 3.94%. This change is not the same as 3.74% which is the observed change in the probability when workshop attendance increases from 2 to 3. The reason for the difference is that the partial derivative represents a change in the tangent line at a particular point in the logistic curve rather than the logistic curve itself (Kaufman, 1996; Kim and Giestfeld,

2004). Therefore, the partial derivative (3.94%) is slightly different from the actual change (3.74%) in the logistic curve.

To examine the marginal effect of using no-till production methods, the following computation is used:

Z_i (NOTILL=0| all other variables = means and reference categories)

$$Z_i = 2.950 + (.701)*0 + (.699)*0 + (1.161)*0 + (-.837)*0 + (-.043)*58.29 + (.204)*.85 + (.001)*188.95 = .8059$$

$$\Pr(Y = 1) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] = .6912 = 69.12\%$$

Z_i (NOTILL=1| all other variables = means and reference categories)

$$Z_i = 2.950 + (.701)*1 + (.699)*0 + (1.161)*0 + (-.837)*0 + (-.043)*58.29 + (.204)*.85 + (.001)*188.95 = 1.5069$$

$$\Pr(Y = 1) = \left[\frac{\exp(Z_i)}{1 + \exp(Z_i)} \right] = .8185 = 81.85\%$$

Evaluated at the means and omitted categories of the independent variable, the probability of choosing to grow switchgrass for farmers who use no-till production methods is 12.73 % higher than those who do not use no-till production methods.

Impacts of Factors

The estimated coefficients of the binary logit model are presented in table 20. TACF, NERO, NOTILL, AGE, OCOMP, HOAW, and ENVIR significantly affect the

probability of switchgrass adoption. The results indicate that farmers with larger farms, use no-till production methods, belong to an environmental organization, attend extension workshops, and those that own a computer will be more likely to adopt switchgrass. Farmers that do not have an erosion problem on farmland will be less likely to adopt switchgrass as well as older farmers. Having heard of switchgrass, experience, education, and farm tenure do not significantly affect the probability of adoption.

Predictions for Don't Knows

The logit model correctly classified respondents who were interested in growing switchgrass 87.21% of the time, while predicting those who were not interested in growing switchgrass correctly roughly half of the time. Overall, the model gave 74.1% correct predictions of adopters and non-adopters. It is assumed that information is the main factor in the indecision to grow switchgrass for those respondents who answered 'don't know but would like further information' on the survey.

The forecast rates of adoption for those in the 'don't know' category are shown in Table 21. Using the significant factors that affect the decision to adopt switchgrass, an equation was formulated using the estimated coefficients from the logit model.

Regression equation:

$$Z_i = 2.95 + (.001)*TACF + (-.837)*NERO + (.701)*NOTILL + (-.043)*AGE + (.699)*(OCOMP) + (.204)*HOAW + (1.161)*ENVIR$$

Information collected from the survey participants that answered 'don't know, but would like further information' was used in the regression equation to predict if these farmers would adopt switchgrass if given more information. The sample consisted of 892

Table 21. Mean characteristics of "don't know" farmers by adoption groups of switchgrass.

	Not Adopting N=114	Adopting N=778
Sample	12.78%	87.22%
Has heard of switchgrass	9.6%	18.5%
Owns hay equipment	82.5%	81.1%
Currently uses no-till production methods	7.9%	52.3%
Owns personal computer	15.8%	73.9%
Currently belongs to a grower or commodity organization	0.9%	5.1%
Currently belongs to a hunting-related organization	4.4%	11.7%
Currently belongs to an environmental organization	0%	4.9%
Currently belongs to a Farm Bureau	82.5%	79.0%
Currently belongs to a cooperative	38.6%	56.2%
Net income from farming in 2004 (after taxes) is less than \$75K	100%	98.2%
Currently has a Conservation Compliance Program	3.5%	15.4%
Does not have a Conservation Compliance Program, but practice erosion control	2.6%	31.4%
No significant erosion problem on farmland	84.2%	42.2%
Significant erosion control program, but erosion control practices are not used	5.3%	4.8%
Other farm situation	4.4%	6.3%
A full owner of farming business	80.7%	74.6%
A part owner of farming business	12.3%	16.8%
A renter of farming business	1.8%	2.2%
A limited liability corporation farming business	0%	0.6%
A cooperative farming	0%	0.10%
Other farming business	5.3%	5.7%
College graduate	87.7%	86.6%
Age in years	71.18	56.04
Years of farming experience	45.90	36.53
How often attends workshops	.21	.92
Total acres farmed	110.38	190.86

respondents. If given more information, the regression suggests that 87% of those that indicated they needed more information would plant switchgrass. Differences in the mean characteristics show that adopters are more likely to own a computer, own more acres of land, be younger, and use no-till production methods.

Conclusions

The factors affecting a farmers' decision to either adopt or not adopt switchgrass for energy were analyzed using a logit model. The changes in the probability of adoption associated with changes in the farm and socio-economic characteristics of the farmer were computed. The analysis went on further to predict future adoption of farmers who did not know if they would adopt switchgrass if they were given more information using a regression equation that was formulated with the coefficients computed in the logit model.

The results of the analysis of the factors influencing the decision to adopt switchgrass indicated that the adoption behavior of farmers is influenced by economic, institutional, and physical factors. Farm related characteristics such as total acres farmed, no erosion problem, and the use of no-till production methods, and socio-economic characteristics such as age, attendance at extension education programs, membership in farm related organizations, significantly influenced the farmers' decision to grow switchgrass. Therefore, it is reasonable to conclude that adequate consideration of these variables may greatly contribute to increase the adoption rate of switchgrass.

After applying the logit model to those that indicated they did not know, roughly 87% of farmers who did not know if they would grow switchgrass would decide to grow

switchgrass if given more information. These findings have implications for policy-makers in that extension efforts should be planned for educating farmers about switchgrass adoption and research efforts should be promoted for making easy to understand economic thresholds.

References

- Adesina, A. A. and Zinnah, M. M. 1993. Technology characteristics, farmers' perceptions, and adoption decisions: A tobit model application in the Sierra Leone. *Agricultural Economics* 9, 297-311.
- Ahmad, Z., Byerlee, D., Azeem, K., 1995. Factors affecting adoption of semi-dwarf wheat in marginal areas: evidence from the rain fed northern Punjab. PARC, Islamabad.
- Agriculture Marketing Resource Center. <http://www.agmrc.org/agmrc/>
- Amemiya, T. "Qualitative Response Models: A Survey" *Journal of Economic Literature* 19(1981):1483-1536.
- Batte, M. and Johnson R. 1993. Technology and its impact on American agriculture. In: *Size, Structure, and the Changing Face of American Agriculture*, edited by A. Hallum (Westview Press Inc., Boulder, CO, USA).
- Beale, G. and Bolen, J. 1995. *How Farm People Accept New Ideas*. Cooperative Extension Report No. 15, Iowa State University, Ames, IA, USA.
- Bender, Marty. Energy in Agriculture and Society: Insights from the Sunshine Farm. Land Institute, 2001. Washington DC.
- Boz, Ismet and Cuma Akbay. 2004. Factors influencing the adoption of maize in Kahramanamaras province of Turkey. *Agricultural Economics* 33 (2005) supplement 431-440.
- Brander, L. Kearl, B., 1964. Evaluation for congruence as a factor in adoption rate of innovations. *Rural Sociol.* 29(3), 288-303.
- Bultena, G. L. and Hoiberg, E. O. 1983. Factors affecting farmers' adoption of conservation tillage. *Journal of Soil and Water Conservation* 38(3), 281-283.
- Burden, D. 2003. Switchgrass Industry Profile. Agricultural Marketing Resource Center.
- Bransby, D.I. 1999. The value of survey information on the potential to grow switchgrass for energy in Alabama. In: *Biomass: A growth opportunity in green energy and value added products*. Proc. 4th Biomass Conf. Americas, Oakland, California, Aug. 29 – Sept. 2. 1747-1751.
- Daberkow, Stan G. and William McBride. 2003. Farm Operator Characteristics Affecting the Awareness and Adoption of Precision Agriculture Technologies in the US. *Precision Agriculture* 4, 163-177.

De La Torre Ugarte, Daniel G., Marie E. Walsh, Hosein Shapouri, and Stephen P. Slinsky, 2003. The Economic Impacts of Bioenergy Crop Production on US Agriculture. U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report No. 816.

DeMaris, A. (1992). Logit modeling: Practical applications. *Sage University Papers Series on Quantitative Applications in the Social Sciences*, 07-86. Thousand Oaks, CA: Sage.

Dillman, D. A. (2000). *Mail and Internet surveys: The tailored design method* (2nd ed.). New York: John Wiley & Sons, Inc.

D'Silvia, Brian C.D. and Obliana, A. Tunde. 1981. Developing and transferring 'new' crop technologies: modifying farming systems in northern Nigeria. Africa and Middle East Branch, International Economics Division, Economic Research Service. Washington, D.C.

Farrell, A., R. Plevin, B. Turner, A. Jones, M. O'Hare, D. Kammen.
Ethanol Can Contribute to Energy and Environmental Goals. *Science* 27 January 2006: Vol. 311. no. 5760, pp. 506 - 508

Feder, G. Farm Size, Risk Aversion and the Adoption of New Technology under Uncertainty. *Oxford Economic Papers* 32 (July 1980): 263-283.

Feder, G. and Umali, D.L. 1993. The adoption of agricultural innovations: A review. *Technological Forecasting and Social Change* 43, 215-239.

Feder, G., Just, R.J., and Zilberman, D. 1985. Adoption of agricultural innovations in developing countries: A Survey. *Economic Development and Cultural Change* 33(2), 255-298.

Gasson, R. (1973), The goals and values of Farmers. *Journal of Agricultural Economics* 24, 521-542.

Goldemberg J., T.B. Johansson, A.K.N. Reddy and R.H. Williams. 1987. *Energy for a Sustainable World*. World Resources Institute, Washington, DC.

Gould, B.W., Saupe W.E. and Klemme R.M. 1989. Conservation tillage: the role of farm and operator characteristics and the perception of erosion. *Land Economics* 65: 167-182.

Gujarati, D. 1999. *Essentials of econometrics*. Irwin/McGraw-Hill, Boston, USA.

Hewitt, William Joseph. 1997. Economic feasibility of switchgrass production and utilization in Tennessee. Thesis (PhD) University of Tennessee, Knoxville.

Hiebert, L. D. 1974. Risk, learning, and the adoption of fertilizer responsive seed varieties. *American Journal of Agricultural Economics* 56, 764-768.

Hosmer, D. W., and Lemeshow, S. (1989). *Applied logistic regression. Wiley series in probability and statistics*. New York: Wiley-Interscience. 392pp.

Hullar, Theodore L. 1991. Sustainable agriculture research and education in the field: a proceedings / Board on Agriculture, National Research Council. National Academy Press. Washington, D.C.

Ikerd, John. Sustainability's Promise. *Journal of Soil and Water Conservation* (Jan.-Feb. 1990) 45(1): p4.

Janicick, S.F. and T.H. Klindt. An Analysis of 'no-tillage' Practice Decisions. Department of Agricultural Economics and Rural Sociology, University of Tennessee, USA (1995).

Judge, G., W. Griffiths and R.C. Hill. *The Theory and Practice of Econometrics*. John Wiley and Co, New York (1980).

Just, R. and D. Zilberman. Stochastic Structure, Farm Size, and Technology Adoption in Developing Agriculture. *Oxford Economic Papers* 35 (August 1983): 307-328.

Kaufman, R.L. (1996). Comparing effects in dichotomous regression: A variety of standardized coefficients. *Social Science Quarterly*, 77, 90-109.

Khanna, M. and Zilberman, D. 1997. Incentives, precision technology, and environmental protection. *Ecological Economics* 23, 25-43.

Kim, E., & Geistfeld, L. V. 2004. Is she working enough? Rural poor women's unemployment and depression. Proceedings of 2003 Rural Sociological Society annual meeting. Available at: <http://www.ruralsociology>

King, R.N., and T.J. Rollins. 1995. Factors influencing the adoption of nitrogen testing program. *J. Extension* 33(4). <http://www.joe.org>

Liao, T.F., 1994. *Interpreting Probability Models: Logit, Probit, and Other Generalized Linear Models*. Sage, Thousand Oaks, CA.

Maddala, G. S., 1992. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge.

McDaniels, P. Producing Switchgrass: Milan Tour to Focus on Timely Topic. UT Institute of Agriculture Marketing and Communications <http://milan.tennessee.edu>.

McLaughlin, S., J. Bouton, D. Bransby, B. Conger, W. Ocumpaugh, D. Parrish, C. Taliaferro, K. Vogel, and S. Wullschlegel, 1999. "Developing Switchgrass as a Bioenergy Crop," in *Perspectives on New Crops and New Uses*. J. Janick (ed). ASHA Press; Alexandria, VA.

McNamara, Kevin T., Michael E. Westzstein, and G. Keith Douce. Factors Affecting Peanut Producer Adoption of Integrated Pest Management. *Review of Agricultural Economics*, Vol. 13, No.1 (Jan., 1991), pp. 129-139.

Mernard, S. (1995). Applied logistic regression analysis. *Sage University Papers Series on Quantitative Applications in the Social Sciences*, 07-106. Thousand Oaks, CA: Sage.

Mizrahi, Y. 1995. The profitability of government funding of new crop research and development. *Austral. New Crops Newslett.* 4:13.
(www.newcrops.uq.edu.au/newslett/ncnl4-11.htm)

Nell, W. T. 1998. *Transfer and adoption of technology: The case of sheep and goat farmers in Qwaqwa*. Unpublished Ph.D. thesis. University of the Orange Free State, Bloemfontein. <http://www.uovs.ac.za/faculties/agric/centre>

Norris, P.E., Batie, S.S., 1987. Virginia farmers' soil conservation decisions: An application of probit analysis. *Southern J. Agric. Econ.* 19(1), 19-90.

Pampel, F.C. (2000). Logistic regression: a primer. *Sage University Papers Series on Quantitative Applications in the Social Sciences*, 07-132. Thousand Oaks, CA: Sage.

Pannell, D.J. (1999). Uncertainty and Adoption of Sustainable Farming Systems, Paper presented at the 43rd Annual Conference of the Australian Agricultural and Resource Economics Society, Christchurch, New Zealand, January 20-22 1999. (SEA Working paper 99/01) abstract. Full paper (50K). Later published as: Pannell, D.J. (2003). Uncertainty and Adoption of Sustainable Farming Systems. in B.A. Babcock, R.W. Fraser and J.N. Lekakis (eds), *Risk Management and the Environment: Agriculture in Perspective*, Kluwer, Dordrecht, pp. 67-81.

Petersem, T. (1985). A comment on presenting results from logit and probit models. *American Sociological Review*, 50(1), 130-131.

Rick S. Llewellyn, Robert K. Lindner, David J. Pannell & Stephen B. Powles (2002). Adoption of herbicide resistance management practices by Australian grain growers, SEA Working Paper 02/06, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia. full paper (127K)

- Rogers, E.M. 1995. Diffusion of innovations. 4th ed. New York: The Free Press.
- Rogers, E.M., Pitzer, R.L., 1960. The adoption of irrigation by Ohio farmers. Ohio Agri. Exp. Sta. Bul., 851 Wocester.
- Ryan, B., Gross, N.C., 1943. The diffusion of hybrid seed corn in two Iowa communities. Rural Sociol. 13, 273-285.
- Sevier, Brian, and Won Suk Lee. Precision Farming Adoption by Florida Citrus Producers: Probit Model Analysis. <http://edis.ifas.ufl.edu/AE283>.
- Schaller, N. 1993. The Concept of Agricultural Sustainability. Agri. Ecosyst. Env., 46:89-97.
- Sheikh, A.D., S. Zia, and M. Aslam. Conservation tillage wheat cultivation technology. In: A. Jabbar, Editor, Sustainable Agriculture and Environmental Conservation, Sustainable Development Policy Institute, Islamabad (1994), pp. 28-51.
- Shortle, J.S. and J.A. Miranowski. Effect of Risk Perceptions and Other Characteristics of Farmers and Farm Operations on the Adoption of Conservation Tillage Practices. Department of Agricultural Economics, University of Pennsylvania State University, USA (1986).
- Union of Concerned Scientists (UCSUSA).
http://ucsusa.org.food_and_enviornment/sustainable_agriculture/page.com
- Wallis, E.S., I.M. Wood, and D.E. Byth. 1989. New crops: A suggested framework for their selection, evaluation, and commercial development. In: G.E. Wickens, N. Haq, and P.Day, New crops for food and industry. Chapman and Hall, London.
- Worldwatch Institute. State of The World 2002. W. W. Norton & Company (January 2003).
- Young, C.E. and J.S. Shortle. 1984. Investments in soil conservation structures: The role of operator and operation characteristics. *Agricultural Economics Research* 36(2): 10-5.
- Zunes S., “A Mis-statement of the Union Address,” (Silver City, NM & Washington, DC: Foreign Policy In Focus, February 1, 2006).

Part 4: Conclusions

Conclusions

This study analyzed the factors influencing the decision to adopt switchgrass for energy production. A chi-square test of independence was used to determine whether significant differences existed among interested respondents and non-interested respondents in terms of the selected socioeconomic characteristics. The factors affecting farmers' decision either to adopt or not to adopt switchgrass for energy were analyzed using a logit model. The changes in the probability of adoption associated with changes in the farm and socio-economic characteristics of the farmer were computed. The analysis went on further to predict future adoption of farmers who did not know if they would adopt switchgrass if they were given more information using a regression equation that was formulated with the coefficients computed in the logit model.

The results of the analysis of the factors influencing the decision to adopt switchgrass indicated that the adoption behavior of farmers is influenced by economic, institutional, and physical factors. Farm related characteristics such as total acres farmed, no erosion problem, and the use of no-till production methods, and socio-economic characteristics such as age, attendance at extension education programs, membership in farm related organizations, significantly influenced the farmers' decision to grow switchgrass. The regression equation formulated concluded that roughly 87% of farmers who did not know if they would grow switchgrass would decide to grow switchgrass if given more information. These findings have implications for policy-makers in that extension efforts should be planned for educating farmers about switchgrass adoption and research efforts should be promoted for making easy to understand economic thresholds.

Vita

Pamela Catherine Ellis was born in Mobile, Alabama on April 19, 1978. She graduated from UMS-Wright Preparatory High School in 1996. The following August, she entered the University of Alabama in Tuscaloosa, Alabama. There she earned a Bachelors' of Science in Finance in 2000.

In 2002, she entered the University of Alabama at Birmingham where she obtained a Masters of Business Administration. In August, 2004, she entered the University of Tennessee's Master of Science program in Agricultural Economics. She completed the Master of Science degree in December 2006.