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ANALYSIS OF FACTORS AFFECTING FARMERS' WILLINGNESS TO ADOPT SWITCHGRASS PRODUCTION IN THE SOUTHERN UNITED STATES AND AN EXCEL SPREADSHEET-BASED DECISION TOOL FOR POTIENTIAL SWITCHGRASS PRODUCERS

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To the Graduate Council:

I am submitting herewith a thesis written by Donald Joshua Qualls entitled "ANALYSIS OF FACTORS AFFECTING FARMERS' WILLINGNESS TO ADOPT SWITCHGRASS PRODUCTION IN THE SOUTHERN UNITED STATES AND AN EXCEL SPREADSHEET-BASED DECISION TOOL FOR POTIENTIAL SWITCHGRASS PRODUCERS." 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.

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ANALYSIS OF FACTORS AFFECTING FARMERS' WILLINGNESS TO ADOPT SWITCHGRASS PRODUCTION IN THE SOUTHERN UNITED STATES ANDAN EXCEL SPREADSHEET-BASED DECISION TOOL FOR POTIENTIAL SWITHGRASS PRODUCERS

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ABSTRACT

The increased need for and scarcity of hydrocarbon energy pushes the search and extraction of reserves toward more technically difficult deposits and less efficient forms of hydrocarbon energy. The increased use of hydrocarbons also predicates the increased emission of detrimental chemicals in our surrounding environment. For these reasons, there is a need to find feasible sources of renewable energy that could prove to be more environmentally friendly.

One possible source that meets these criteria is biomass, which in the United States is the largest source of renewable energy as it accounts for over 3 percent of the energy consumed domestically and is currently the only source for liquid renewable transportation fuels. Continued development of biomass as a renewable energy source is being driven in large part by the Energy Independence and Security Act of 2007 that mandates that by 2022 at least 36 billion gallons of fuel ethanol be produced, with at least 16 billion gallons being derived from cellulose, hemi-cellulose, or lignin. However, the production of biomass has drawbacks. The market for cellulosic bio-fuel feedstock is still under development, and being an innovative technique, there is a lack of production knowledge on the side of the producer.

Some studies have been conducted that determine farmers' willingness to produce switchgrass, however, they have been limited in geographic scope and additional research is warranted considering a broader area. Also, there have been production decision tools aimed at bio-mass, but these have either not been aimed at switchgrass specifically or have been missing key costs such as those incurred in storage. The overall objectives of this study are: 1.) to analyze the willingness of producers in the southeastern United States to plant switchgrass as a biofuel feedstock, 2.) to estimate the area of switchgrass they would be willing to plant at different switchgrass prices, 3.) to evaluate the factors that influence a producer's decision to convert acreage to switchgrass, and 4.) to present a spreadsheet-based decision tool for potential switchgrass producers.

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Part 1: Introduction

Introduction

Much of the energy used in the industrialized world comes from fossil fuels such as coal, petroleum, and natural gas. Although these chemicals are still being created underground by the forces of heat and pressure, they are being consumed in quantities far exceeding the formation of new reserves. This increased need for and scarcity of hydrocarbon energy pushes the search and extraction of reserves toward more technically difficult deposits and less efficient forms of hydrocarbon energy. The increased use of hydrocarbons also predicates the increased emission of detrimental chemicals in our surrounding environment. For these reasons, there is a need to find feasible sources of renewable energy that could prove to be more environmentally friendly.

One of these sources of renewable energy that has been the subject of much research is biomass. Biomass is material derived from living or once living organisms such as herbaceous and woody plant constituents and animal wastes that can be used to make solid, liquid, and gaseous fuels. It is the largest source of renewable energy accounting for over 3 percent of the energy consumed domestically and is also currently the only source for liquid renewable fuels used in transportation (Perlack et al. 2005).

Of the possible ways to take advantage of direct and indirect energy from the sun, biomass use is promising because it is compatible with current technologies and it can be stored without technical problems which allows for its energy to be used when needed (Kaltschmitt 1994). Biomass could prove to be a clean energy source as it absorbs the carbon that it releases during combustion from the atmosphere, potentially making it carbon neutral.

The source of biomass that will be the focus of this study is switchgrass. Switchgrass is a C_4 carbon fixation perennial warm season grass (Lewandowski et al. 2003). The perennial nature of switchgrass gives it the advantage over annual crops for cellulosic biomass because it does not have fixed annual establishment requirements. Its native habitat includes the prairies, open ground and wooded areas, marshes, and pinewoods of much of North America east of the Rocky Mountains and south of 55°N latitude (Stubbendieck et al. 1991). There are two distinct geographic varieties or ecotypes of switchgrass: lowland and highland (Porter 1966; Brunken and Estes 1975). Lowland types can be found on flood plains and other areas that may be subject to inundation and upland types can typically be found in areas that have a low potential to flood (Vogel 2004). Lowland types tend to be taller, coarser, and show the ability to grow more rapidly than upland types (Vogel 2004).

There are many benefits that could be realized from the planting of switchgrass as a biomass feedstock for fuel. Switchgrass has the capability to show high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003). Being a native species, it also has a natural tolerance to pest and diseases and can be grown successfully throughout a large portion of the United States with minimal fertilizer applications (Jensen et al. 2007), which would be cost efficient and less disruptive to the surrounding environment. Switchgrass has the capability to show high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003), meaning that the grass could add profitability to land that may not be economically useful otherwise. It has the positive attribute of reducing erosion due to its extensive root system and canopy cover (Ellis 2006) and shows the potential ability to reduce the buildup of CO_2 by being a feedstock for a cleaner burning fuel than fossil fuels and through soil carbon sequestration due it is being a deep rooted crop (Ma et al.2000).

Growing switchgrass as a biomass feedstock crop would add diversity to the American crop mix. Introducing a new crop, like switchgrass, into a two crop rotation such as the corn-soybean rotation that dominates the Corn Belt can help alleviate pest buildups that demand the increased use of pesticides (Janick et al. 1996). Additionally, the introduction of new crops into agricultural production can increase and protect farm income by diversifying farm products, hedging risks, and expanding markets and can also act as a catalyst for rural economic development by creating locally based processing and packaging industries (Janick et al. 1996).

Despite the potential benefits that could be realized from the planting of switchgrass, there are significant obstacles to overcome. Several factors would have to be taken into consideration before a bio-refinery that utilizes switchgrass to produce ethanol could be established in a given area. Because of the high cost associated with the transportation of biomass from switchgrass, the area from which a bio-refinery would feasibly be able to draw feedstock would need to be small, preferably within a 30 mile radius (Mitchell, Vogel, and Sarath 2008). This means that it would have to be determined if the local farmers would be willing to devote sufficient acreage to switchgrass to meet the needs of the bio-refinery. This willingness will be a function of numerous factors including biomass feedstock profits, variability of profits, and correlation of profits relative to traditional crop profits (Larson et al. 2005).

The large scale production of switchgrass as a bio-energy feedstock is still in the developmental stage. Consequently, a lack of an established market and of knowledge exists both on the part of the producer pertaining to the costs and activities associated with its production and on the part of the researcher pertaining to farmer's willingness to produce and attitudes toward switchgrass. While some studies have focused on factors that determine farmers' willingness to produce switchgrass and their general attitudes toward switchgrass and its production (e.g. Jensen et al. 2007; Bransby 1998; Wen et al. 2005), these studies have been limited in geographic scope and additional research is warranted that considers a broader geographical area and different variables in order to gain a more complete understanding of how producers view biomass feedstock production.

Knowledge of where switchgrass is likely to be adopted and the factors that are involved in the producers' decisions to adopt are of critical importance to understanding the potential development of switchgrass as an energy feedstock at a market level. Additionally, with switchgrass being a new crop, many producers may not be familiar with the production costs associated with growing switchgrass. An understanding of these costs is crucial in the producers' decisions of if and to what extent they would be willing to produce switchgrass. That stated, a financial decision tool would be of assistance to producers in making these production decisions.

Objectives

The overall objectives of this study are: 1.) to analyze the willingness of producers in the southeastern United States to plant switchgrass as a biofuel feedstock, 2.) to estimate the area of switchgrass they would be willing to plant at different switchgrass prices, 3.) to evaluate the factors that influence a producer's decision to convert acreage to switchgrass, and 4.) to present a spreadsheet-based decision tool for potential switchgrass producers.

This thesis is organized into two major sections. The first section is a paper that focuses on the factors pertaining to farmers' interest in planting switchgrass and those that are associated with their likelihood and the extent to which they would be willing to produce switchgrass given different plant gate prices. To accomplish this, a Tobit specification model with a binary sample selection rule will be used. The binary sample selection rule will be used to analyze the producers' interests in growing switchgrass and the Tobit model is used to estimate acreage adoption in response to switchgrass prices and other variables if the producer shows interest in growing switchgrass.

The second section of this thesis is a paper that describes and documents an interactive producer decision tool. This tool is an excel workbook that contains an intereactive switchgrass budget. The tool provides the user with detailed information on the costs incurred in each stage of a switchgrass operation in each year of its duration, which, for the purposes of this analysis, will be 10 years. The decision tool is broken down into 13 different worksheets, including:

- welcome worksheet
- tutorial worksheet
- input-output worksheet
- cash flow worksheet
- cost distribution worksheet
- yearly cash flow worksheet
- accumulated cash flow
- planting and establishment worksheet

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Part 2: Analysis of Factors Affecting Farmers' Willingness to Adopt Switchgrass Production in the Southern United States

Introduction

In the United States, biomass is the largest source of renewable energy accounting for over 3 percent of the energy consumed domestically and is at present the only source for liquid, renewable, transportation fuels (Perlack et al. 2005). The continued development of biomass as a renewable energy source is being driven in large part by the Energy Independence and Security Act of 2007 (EISA). The EISA is an energy policy law that mainly deals with increasing energy efficiency and the availability of energy from biomass. The Act included three key provisions: Corporate Average Fuel Economy (CAFE)Standards, Appliance and Lighting Efficiency Standards, andRenewable Fuel Standard (RFS) (Sissine 2007). The Renewable Fuel Standard mandates that by 2022 at least 36 billion gallons of ethanol for fuel be produced in the United States, with at least 16 billion gallons being ethanol that is derived from cellulose, hemi-cellulose, or lignin (U.S. Congress 2007).While EISA calls for increased production of cellulosic-based fuels, the market for cellulosic-based fuels is still under development. Development of a cellulosic-based fuel industry will rely not only on construction and operation of conversion facilities, but also reliable, cost-efficient, and environmentally sustainable cellulosic feedstock sources.

Several potential reasons for promoting the production of cellulosic ethanol in favor of ethanol from cornstarch exist. Corn, which also has use as animal feed and human consumption, will not be grown in sufficient quantities to meet the feedstock demand for fuel ethanol and is not likely to displace current transportation fuels to a significant extent (Hahn-hagerdal et al. 2006, Lynd 1991). Because cellulosic fuels are not based upon a human or animal feed source, cellulosic feedstock development would likely create minimal market pressure on food or animal feed markets. Environmental benefits relative to the production of corn based ethanol may accrue from production of cellulosic ethanol. Some perennial cellulosic energy crops have the potential for reduced erosion due to being deep rooted plants and to require less chemical applications than traditional row crops such as corn (Bransby)In addition, the production of cellulosic ethanol is likely to show a higher reduction in green house gases than would the production of corn based ethanol (Wang 2008).

Of the possible ways to take advantage of direct and indirect energy from the sun, biomass use is promising, because it is compatible with current technologies and it can be stored without technical problems which allows for its energy to be used when needed (Kaltschmitt 1994). Biomass could prove to be a clean energy source as it absorbs the carbon that it releases during combustion from the atmosphere, potentially making it carbon neutral.

Approximately 19 years ago, The Bio-energy Feedstock Program based at Oak Ridge National Laboratory concluded that more emphasis was needed on developing herbaceous bio-energy crops that could "combine close compatibility of crop management strategies with existing farming practices, generate cash flow from annual returns from harvested biomass, and have positive environmental impacts on American farmlands"(McLaughlin and Kszos 2004 p.516). One crop that meets these criteria is switchgrass (*Panicum vergatum*). Switchgrass is a C_4 carbon fixation perennial warm season grass (Lewandowski et al. 2003). Native habitat includes the prairies, open ground, open woods, marshes, and pinewoods of much of North America east of the Rocky Mountains and south of 55°N latitude (Stubbendieck et al. 1991).

Several advantages to planting switchgrass as a biomass feedstock exist. Switchgrass has a natural tolerance to pest and diseases and can be grown successfully throughout a large portion of the United States with minimal fertilizer applications (Jensen et al. 2007). Requiring low amounts of fertilizer and pesticide per acre is cost efficient and less disruptive to the surrounding environment. Switchgrass has the capability to show high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003), meaning that the grass could add profitability to land that may not be economically useful otherwise. Switchgrass has the positive attribute of reducing erosion due to its extensive root system and canopy cover (Ellis 2006), and has the potential ability to reduce the buildup of CO_2 by being a feedstock for a cleaner burning fuel than fossil fuels and by soil carbon sequestration due it is being a deep rooted crop (Ma et al.2000).

Growing switchgrass as a biomass feedstock crop would add diversity to the American crop mix. Diversification of cropping systems brings with it the possibility of many benefits. Introducing a new crop, like switchgrass, into a two crop rotation such as the corn-soybean rotation that dominates the Corn Belt can help alleviate pest buildups that demand the increased use of pesticides (Janick et al. 1996). Additionally, the introduction of new crops into agricultural production can increase and protect farm income by diversifying farm products, hedging risks, and expanding markets and can also act as a catalyst for rural economic development by creating locally based processing and packaging industries (Janick et al. 1996).

For cellulosic ethanol to be produced in sufficient quantities to have a significant impact on the mix of energy inputs used in the United States, the large scale production of dedicated energy crops will be required. However, a major hurdle to overcome is the lack of an established market for cellulosic bio-mass feedstock. For a cellulosic feedstock market to develop producers will have to be willing to plant dedicated energy crops on a massive scale and cellulosic ethanol refineries will have to be available to purchase and convert the biomass to fuel. For instance, a 50 million gallon per year ethanol plant will require 464,253 short tons of feedstock if it is assumed that 107.7 gallons of ethanol can be produced from one ton of feedstock (Lynd 1996).

The EISA requires 16 billion gallons, and using 50 million gallon plants as an example, it means approximately 320 plants would be required. These 320 plants would require roughly 148,561,000 tons of switchgrass to meet production goals. Because of the high cost associated with the transportation of biomass the area from which a bio-refinery would feasibly be able to draw feedstock would need to be small, preferably within a 30 mile radius (Mitchell, Vogel, and Sarath 2008). Thus it would be critically important to determine if local producers would be willing to devote sufficient acreage to cellulosic feedstock to meet the needs of the bio-refinery. This willingness to grow cellulosic feed stock will be a function of numerous factors including the amount and variability of feedstock profits and the relationship of feedstock profits relative to traditional crop profits (Larson et al. 2005).

Most studies pertaining to switchgrass have focused on breeding, conversion technologies, and logistics as well as production cost, non bio-refinery commercial applications, and the nature of future demands for switchgrass for energy consumption (Jensen et al.2007; Wen et al. 2009). It is pointed out by Wen et al. (2009) that there is a lack of understanding of feed stock production from the farmers' perspective. While there have been some studies done on factors that determine farmers' willingness to produce switchgrass (e.g. Jensen et al. 2007; Bransby 1998; Wen et al. 2009), these studies have been limited in geographic scope and additional research is warranted that considers a broader geographical area and different variables in order to gain a more complete understanding of how producers view biomass feedstock production.

Objectives

The objectives of this study are: 1.) to analyze the willingness of producers in thesoutheastern United States to plant switchgrass as a biofuel feedstock, 2.) to estimate the area of switchgrass they would be willing to plant at different switchgrass prices, and 3.) to evaluate the factors that influence a producer's decision to convert acreage to switchgrass.

In this section of the study, the focus will be on the factors pertaining to farmers' interest in planting switchgrass and those that are associated with their likelihood and the extent to which they would be willing to produce switchgrass given different plant gate prices. To accomplish this, a Tobit specification model with a binary sample selection rule will be used. The binary sample selection rule will be used to analyze the producers' interests in growing switchgrass and the Tobit model is used to estimate acreage adoption in response to switchgrass prices and other variables if the producer shows interest in growing switchgrass. This research will aide in the understanding of how feasible cellulosic ethanol production will be in areas of the southeastern U. S. depending on the area's farmer demographic and production trends. This knowledge will aide federal, state, and local governments in making more informed decisions concerning laws and regulations pertaining to switchgrass and cellulosic ethanol production.

Review of Literature

Empirical Adoption Studies

The literature on the adoption of new crops and technologies is widely varied, with focuses ranging from the adoption of fertilizers by rice farmers in Côte d'Ivoire (Adesina 1996) to the decision by farmers to adopt soil conservation practices in Virginia (Norris and Batie 1987). Despite these assorted circumstances, there are a number of factors that repetitively show significant influence on adoption decisions. These include both farmer and farm characteristics.

Farmer Characteristics

Age and education are factors that are often taken into account when determining adoption willingness. Previous studies have shown that age has a negative effect on the willingness to adopt technology or innovations (e.g. Daberkow and McBride 1998; Norris and

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

Off-farm and on farm income are factors that have been analyzed by many adoption studies. The effect of off-farm income on innovation adoption is analyzed in multiple studies (e.g. Jensen et al. 2007; Adesina 1996; Norris and Batie 1987; Fernandez-Cornejo, Hendricks, and Mishru 2005). Jensen et al. (2007) found off farm income to have no effect on the share of acres adopted; Norris and Batie (1987) found it to have a statistically significant negative effect on the adoption of an innovative practice; and Fernandez-Cornejo, Hendricks, and Mishru (2005) found it to have a statistically significant positive effect on the adoption of an innovative practice. On farm income's effect on innovation adoption has been analyzed by multiple studies as well (e.g., Jensen et al. 2007; Norris and Batie 1987; Ellis 2006). Ellis (2006) found that having a farm income that is lower than 75,000 dollars had a negative effect on adoption. Jensen et al. (2007) hypothesized that greater on farm income would have a positive effect on the adoption of a new crop, but that on farm income per hectare would have a negative effect due to the increased opportunity cost of converting hectares to switchgrass. Norris and Batie (1987) found that income had a positive effect on new conservation techniques.

The willingness to take financial risk, being more concerned about a large loss than missing out on a substantial gain, and reluctance to try new methods before seeing them work for others are factors that deal with a farmer's perception of risk. Multiple studies have analyzed the way that risk effects adoption of innovation (e.g., Fernandez-Cornejo, Beach, and Huang 1994; Daberkow and Mcbride 1998; Fernandez-Cornejo, Daberkow, and McBride 2001). These studies have found that early adopters tend to be less risk adverse than late adopters or those that never adopt the innovation. Daberkow and McBride (1998) describe late and non-adopters as those who perceive a large amount of production and financial risk associated with an innovation.

Marra, Pannell, and Ghadim (2003) assess agricultural technology adoption literature that focuses on studies that concentrate on the effects that risk, uncertainly, and information have on the adoption process. A historical review of adoption literature is given, pointing out aspects of technology adoption that had been neglected over time such as how the rapid pace of technological could make the delaying of adoption the optimal choice or the role that infrastructure and supply chains play in adoption. The study refers to Linder (1987) which puts general empirical adoption studies into two categories: those that focus on why some producers adopt an innovation while others do not and those that focus on the timing of adoption. The study also notes that research on the economics of technology adoption under uncertainty has taken two separate routes: research that considers technology adoption from the standpoint of in a durable asset that has an uncertain future value and research that analyzes how the riskiness of the technology and the utility of a risk averse decision maker has on the adoption process. After surveying the adoption literature that accounts for risk and uncertainty, it turns its focus to the role that learning and knowledge play in the adoption process, subsequently reviewing the relevant literature. The study then outlines a conceptual framework presented by Abadi, Ghadim, and Pannell (1999) which is designed to be compatible with a divisible technology. It concludes its analysis of technology adoption by surveying emerging issues in risk and technology adoption such as crop biotechnology, precision agriculture, and environmental management technologies.

Farm Characteristics

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

Land ownership is a factor that has been analyzed in multiple studies (e.g., Fernandez-Cornejo, Beach, and Huang 1994;Fernandez-Cornejo, Daberkow, and Mcbride 2001; Jensen et al. 2007; Ellis 2006). The results have shown inconsistencies in its effects on the rate of adoption. These inconsistencies are thought to be due to the nature of the innovation being such that it is tied to the land, in the instance of switchgrass, or it does not require land tied investments, as is the case for bio-engineered crops (Fernandez-Cornejo, Daberkow, and Mcbride 2001).

Paulrud and Laitila (2010) is a study of how Swedish farmers feel about the characteristics of dedicated energy crops and to grow them. The plant species used in the study were willow, hemp, canary grass, and energy grain. The survey used two separate choice experiments for the survey, with the first providing information on how farmers value the characteristics of energy crops including rotation length, harvesting technique, landscape impact, and net income, and the second modeling the willingness of farmers to grow energy crops at different levels of incomes and subsides and taking into account farmer and farmer characteristics. Results showed that the utility that each farmer would receive from each respective crop depended not only on the net income, but also on the afore mentioned characteristics of each crop. Significant factors affecting the willingness to grow energy crops included farmer age, farm size, and geographic area.

Switchgrass Survey Studies

There are multiple examples of studies based on surveys of actual or potential switchgrass producers (e.g. Bransby 1998; Hipple and Duffy 2002; Jensen et al. 2007; Wen et al. 2009; Kelsey and Franke 2009). Most of these studies did not rely on any models or regression; rather, they relied on sample statistics to come to their conclusions (e.g. Bransby 1998; Wen et al. 2009; Kelsey and Franke 2009). Hipple and Duffy (2002) did not make use of any numerical values, instead relying on verbal answers to come to generalized conclusions.

Velandia et al. (2010) is a switchgrass study based on interviews with producers, Extension specialists, and researchers as well as surveys of switchgrass producers that analyzed producer viewpoints towards switchgrass production, the producers' social values, the perceived control over a potential high risk project, and their willingness to continue producing switchgrass are their current contract expires. It found that a large percentage of the producers interviewed rated 5 or higher in a scale of 1 to 7, with 1 being unlikely to continue producing switchgrass and 7 being likely to continue producing switchgrass. The results also indicated that producers thought that growing switchgrass as a dedicated energy crop would be economically beneficial and resource efficient through improved average profits, increased stability of profits, and diversification of economic activities. Producers were found to be aware of the challenges facing the production and marketing of switchgrass, such as time spent on equipment breakdown, weed problems, and market development, and felt like these challenges could be overcome.

Bocqueho and Jaquet (2010) examine the effect that liquidity constraints and risk preferences have on the possible extent of switchgrass and miscanthus in the Eure-et-loir region of France. To do this, four different models were used: model zero (M_0) used a normal net present value (NPV) function with a five percent discount rate, M_1 is similar to M_0, but takes into account non-liquidity factors, M_2 is similar to M_0, but takes into account uncertainty related to risk, M_3 is similar to M_0, but takes into account non-liquidity factors and uncertainly related to risk. The study found that switchgrass was a less profitable crop than traditional crops in the study regionusing a standard NPV analysis. An NPV analysis taking into account only non-liquidity factors produced the same result. When only uncertainty was taken into account, the optimal acreage of switchgrass become much higher than in the M_0 or M_1. When both uncertainly and non-liquidity factors were taken into account, an amount much smaller amount of land was allotted to switchgrass than with M_2.

Jensen et al. (2007) analyzed producer willingness to grow switchgrass as a bio-energy feedstock that utilizes the results from a survey of Tennessee farmers. A Tobit model was used to estimate the likelihood and extent to which Tennessee farmers would be willing to produce switchgrass as a new crop for bio-energy. The model showed that 14 of the variables observed were significant to at least the 10 percent level of significance. Of these 14 variables, those that were negatively associated with willingness to grow switchgrass include hectares farmed, the leasing of land, livestock, the need for technical assistance regarding growing and harvesting switchgrass, concern that the markets for switchgrass are not sufficiently developed, the want to provide wildlife habitat on their land, switchgrass harvest limits on Conservation Reserve Program (CRP) land too restrictive, and would consider signing long-term contracts to grow switchgrass for energy. Variables observed that were significant to at least the 10 percent level of significance with a positive coefficient were the practicing of no-till, the growing of soybeans, educational level, and planting period will conflict with planting period of my other crops. While this study provided useful insights, the study was geographically limited.

Conceptual Framework

Farmers are assumed to be rational economic actors that are looking to maximize utility. To do this, they choose the mix of possible uses of their land that obtain the highest level of utility. Let U_i^S represent the expected utility gained from planting switchgrass on a given area of land, U_i^k represent the expected utility from the best of other possible options, Y_i represent acreage share of switchgrass, and U_i represent the difference between the utilities. The difference between the utilities can be shown in equation form as:

$$(1) \qquad U_i = U_i^S - U_i^k$$

A farmer will plant switchgrass on a given section of land if and only if that action is a direct result of the perceived gain in utility being higher from planting switchgrass than it would be from planting the best of other possible options. Following this logic, it can be stated that:

$$(2) \qquad 0 < Y_i \leq 1 \;\Leftrightarrow\; U_i > 0 \; and \; Y_i = 0 \;\Leftrightarrow\; U_i < 0.$$

It is hypothesized by this study that U_i will not be equal to zero. There will be a factor, whether it is observed consciously or subconsciously, that weights a decision to one side or the other. Even if the decision is left up to the toss of a coin, the fact that the toss had an outcome and led to a decision is an additive to utility.

Following Walton et al. (2010), utility for farmer i is stochastic and can be represented as:

$$(3) \qquad U_i = \beta' X_i + \varepsilon_i$$

The deterministic component of utility, $\beta' X_i$, is hypothesized to be a function of exogenous factors (X_i) including demographics, farm characteristics, attitudes toward environmental issues, and the average effect that the exogenous factors have on the adoption and extent of adoption decisions across respondents (β). Random components that affect utility are represented by ε_i. U_i is not directly observable. However, Y_i is a function of U_i and can be estimated using a regression.

X_i could represent a number of factors that can affect the adoption of switchgrass as a crop that the farmer would think to be maximizing his or her utility. Among the many factors that may have an effect on adoption, this study will logically hypothesize that farm size, age, education, off-farm income, and the owning of hay equipment will have a significant effect on the adoption of switchgrass.

Methodology

Statistical Analysis

There have been several studies to use a Tobit model to analyze crop and innovation adoption (e.g., Baidu-Forson 1999; Nkonya, Schroeder, and Norman 1997; Rajasekharan and Veerputhran 2002; Adesina 1996; Ransom, Paulyal, and Adhikari 2003; Jenson et al. 2007). In this study, a zero adoption response could be the result of the producer not being interested in growing switchgrass at any price or that the producer was interested in growing switchgrass, but not at the specific price they were offered in the survey. A true zero response represents those producers that are truly indifferent to growing switchgrass at any price. In some cases, a protest zero response may occur that represents producers that may have otherwise shown interest in the production of switchgrass, but did not find the price offered by his or her particular survey version to be agreeable with payment expectations.

One approach to dealing with the presence of protest bids is the use of a Tobit with binary selection (TBS) model. Following Cho et al. (2008), the TBS model consists of two parts, a binary sample selection rule, which for this study will be used to model the variable describing interest in growing switchgrass, and a censored Tobit model that will estimate acreage adoption based on positive adoption responses and true zero responses to switchgrass price among other variables. The outcomes for switchgrass adoption using this procedure will be either interest (I=0) with no acreage adoption response observed, or interest (I=1) with acreage adoption either censored or positive (A=0 or A>0).

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

(4) $$\text{INTEREST} = 1 if\ z'\alpha + u > 0$$

(5) $$\text{INTEREST} = 0 \text{ if } z'\alpha + u \leq 0$$

and the ACREAGE dependent variable can be expressed as:

(6) $$\text{ACREAGE} = 0\ if z'\alpha + u > 0 \text{ and } x'\beta + v \leq 0$$

(7) $$\text{ACREAGE} = x'\beta + e \text{ if } z'\alpha + u > 0 \text{ and } x'\beta + v > 0$$

(8) $$\text{ACREAGE} = \text{ unobserved if } z^{'}\alpha + u \leq 0$$

where z represents independent variables concerning switchgrass, farm characteristics, and farmer demographics, x represents independent variables concerning switchgrass price, farm characteristics, and farmer demographics, α and β are conformable parameter vectors, and u and v are random error terms.

Again, following Cho et al. (2008), the sample likelihood function is

(9) $$L = \prod\nolimits_{\text{INTEREST}=0}[1 - \Phi(z'\alpha)] \times \prod\nolimits_{\text{INTEREST}=1,\text{ACREAGE}=0} \Psi\,(z'\alpha, -\frac{x'\beta}{\sigma};\ -\rho) \times$$

$$\prod\nolimits_{\text{INTEREST}=1,\text{ACREAGE}\geq 0} \frac{1}{\sigma}\phi(\frac{\text{ACREAGE}-x'\beta}{\sigma}) \times \Phi(\frac{z'\alpha + \frac{\rho(\text{ACREAGE}-x'\beta)}{\sigma}}{(1-\rho^2)^{\frac{1}{2}}}),$$

where Φ is the standard normal cumulative distribution function and Ψ is the bivariate standard normal cumulative distribution function. This formula consists of three components; the first representing the probability of a farmer being uninterested, the second representing the probability of a farmer being interested but unwilling to convert acreage at the specific price, and the third representing the acres that would be converted among the farmers that are interested and are willing to accept the specified price.

To determine if a TBS model is to be used, the estimated value of ρ has to be obtained. If the estimated value for ρ is not significantly different from zero, then a sample selection problem is not statistically significant, and a simpler modeling procedure can be used (English 2002), which in this case means that separate models can be used to analyze the data; a Probit on INTEREST and a Tobit model for ACREAGE. The INTEREST dependant variable can be expressed as:

$$\text{(10)} \qquad \text{INTEREST} = 1 \text{ if } z'\alpha + u > 0$$

$$\text{(11)} \qquad \text{INTEREST} = 0 \text{ if } z'\alpha + u \leq 0,$$

and estimated using a Probit model. The likelihood function is:

$$\text{(12)} \qquad L = \prod_{\text{INTEREST}=0}[1 - \Phi(z'\alpha)] \times \prod_{INTEREST=1} \Phi(z'\alpha).$$

The ACREAGE dependent variable can be expressed as:

$$\text{(13)} \qquad \text{ACREAGE} = 0 \text{ if } x'\beta + e \leq 0$$

$$\text{(14)} \qquad \text{ACREAGE} = x'\beta + e \text{ if } x'\beta + e > 0,$$

and estimated using a Tobit model, which is censored at zero acres to be converted. The likelihood function for the Tobit model is:

$$\text{(15)} \qquad L = \prod_{\text{ACREAGE}=0} 1 - \Phi\left(\frac{x'\beta}{\sigma}\right) \times \prod_{\text{ACREAGE}>0} \frac{1}{\sigma}\phi\left(\frac{\text{ACREAGE}-x'\beta}{\sigma}\right).$$

Hypothesized Effects

SWITSHR is a variable that represents the share of total acres that a producer would be willing to convert to switchgrass production. It is a discrete variable that can have a value between 0 and 1.

INTEREST is a variable representing the producer's interest in growing switchgrass as a crop to be used for energy production. It takes a value of if the producer is at least somewhat interested in growing switchgrass and 0 if the producer is not. A producer's level of interest is hypothesized to be a product of switchgrass characteristics, switchgrass production, and how switchgrass may affect a farming operation.

DEAGE is a variable that represents age of the producer, indexing it by dividing age by ten. With some innovations, the period of time that it would take to see benefit from their implementations could take several years. Intuitively, it can be concluded that a potential adopter of an advanced age would not bother to implement a new technology or plant a new crop because they would not see the payoff from its use. Switchgrass is a perennial crop with a stand life of up to 10 years or more (Lewandowski et al. 2003). Therefore, farmers who do not see their selves farming for that long would be less likely to adopt switchgrass as a crop. This reasoning alone would lead one to think that age would have a negative effect on the adoption of switchgrass; however, other attributes of age have to be considered. With a young farmer that is just starting out, the drive and the willingness to try new things and take risks could be assumed to be higher than a farmer of middle age that may be much more set in his or her ways. That being said, the ability of the middle aged farmer to have access to the funding to start a stand of switchgrass and also to make it through the first two years where the return would not be optimal would in most cases be higher than that of a young farmer. It may be the case that the inability of the young farmer to take the financial risk and the lack of interest of a significantly older farmer might offset each other making the effect and magnitude of age ambiguous on both interest in growing switchgrass and share of acres devoted to switchgrass production.

EDUCATION is a variable that indexes the level of education that the producer has attained. It can have a value of one through six, with one representing elementary/middle school education, two representing some high school, three representing completion of high school, four representing some college, five representing college graduation, and six representing a post graduate degree. Exposure to higher levels of education can increase a farmer's management capacity (Ellis 2006) and allow the producer to more completely understand the beneficial options at his or her disposal. Based on these factors, Ellis (2006) hypothesized that higher levels of attained education would have a positive effect on switchgrass adoption. However, having a more advanced management capacity and a better understanding of the innovations available for adoption could decrease the chance of switchgrass adoption if, in fact, the farm operation in question is less suited to its cultivation. Because of this, it is hypothesized that EDUCATION will have an ambiguous effect on interest in growing switchgrass and the share acres devoted to switchgrass production.

The ownership of hay equipment and the production of hay are represented by the dummy variables HAY1, HAY2, and HAY3. HAY1 has a value of one if the producer both own hay equipment and produces hay. HAY2 has a value of one if the producer has hay equipment but does not produce hay. HAY3 has a value of one if the producer does not have hay equipment but does produce hay. Switchgrass is a crop whose harvesting utilizes the same farm implements as hay (Jensen et al. 2007). If a farmer already produces hay, reason serves to say that they would be more familiar with the process of harvesting grass as a profitable enterprise. Also, they would already either have the equipment necessary for harvest or have a working relationship with a custom harvest service. Jensen et al. (2007) found hay equipment to have a statistically significant positive effect on the hectare share planted to switchgrass. Hence, it is hypothesized that HAY1, HAY2, and HAY3 will have a positive effect on interest in growing switchgrass and percentage of acreage devoted to switchgrass production.

CUSTHAY is a dummy variable that indicates whether or not the producer used a custom hay harvest service in 2008. It has a value of 1 if the producer did use a custom hay harvest service, and a value of 0 if the producer did not use a custom hay harvest service. Using a custom hay harvest service indicates familiarity with the process of producing grass and shows that the producers is experienced in dealing with third parties in said production. Because of this, it is hypothesized that CUSTHAY will have a positive effect on interest in growing switchgrass and the share of acres devoted to switchgrass production.

PRICE is a discrete variable that indexes the different dollar values producers were offered to be willing to sell switchgrass if transportation of the biomass from the farm is provided. The prices offered where 40, 60, 80, 100, and 120 USD. Higher prices offered should have a positive influence on the adoption of switchgrass because it raises the incentive to produce it, therefore price is hypothesized to have a positive effect on the share of acres to be devoted to switchgrass production.

BEEF is a dummy variable that indexes producers' ownership of beef cattle. The variable has a value of one if the producer owns beef cattle and a value of zero if the producer does not. Cattle grazing may compete with switchgrass for pasture acreage and other lands suitable to its production. Also, with owners of beef cattle, switchgrass may have to compete with the production of other established types of grasses that are used conventionally for hay. Therefore

BEEF is hypothesized to have a negative effect on the share of acres devoted to switchgrass production.

DECACRE is a continuous variable representing the size of the producer's farm by indexing the total farm acreage divided by 10. There is a basic hypothesis about technology transfer that the adoption of an innovation will tend to occur earlier on larger farms sooner than on small farms (Fernandez-Cornejo, Daberkow, and McBride 2001). This could be due to the uncertainty of innovation and the fixed cost associated with innovations (Fernandez-Cornejo, Daberkow, and McBride 2001). Generally, it can be assumed that a large farm is the product of a farmer that is more willing to take financial risk. Also, a large farm would have more access to capital in the form of accounting profits made and loans to fund the adoption of a new crop. Ellis (2006) found that total acres farmed had a statistically significant positive effect on switchgrass adoption. For these reasons, it is hypothesized that farm size, Represented by DECACRE, will have a positive effect on interest in growing switchgrass and the share of acres devoted to switchgrass production.

RENTSHR is a variable representing the percentage of the producer's total acreage that is rented from another land owner. Land ownership is widely believed to encourage adoption of innovation (Fernandez-Cornejo, Beach, and Huang 1994). In the case of switchgrass, many of the characteristics and positive attributes of its cultivation lend it toward being planted on land owned by the person doing the farming. These include but are not limited to its long stand life as a perennial, prevention of erosion, and use as wildlife habitat. Jensen et al. (2007) found that the increased percentage of leased land had a negative effect on the hectare share planted to switchgrass. Because of this, it is hypothesized by this study that the percent of land being leased will have a negative effect on the share of acres devoted to switchgrass production.

RELUCTNE is a discrete variable that indexes how a producer feels about taking financial risks and how it affects being a successful farmer. The variable can take on values of one through five, with one being more risk taking and five being more risk adverse. Growing switchgrass as a dedicated energy crop is an innovative production option. Several studies (e.g. Fernandez-Cornejo, Beach, and Huang 1994; Daberkow and Mcbride 1998; Fernandez-Cornejo, Daberkow, and McBride 2001) have found that early adopters of innovations tend to be less risk adverse than those that choose not to be early adopters. Therefore, it will be hypothesized by this study that RELUCTNE will have a negative effect on interest in growing switchgrass and the share of acres devoted to switchgrass production.

LINPUT is a variable that indexes the importance that the producer feels that switchgrass's possibility of having lower fertilizer and herbicide applications as compared to other more conventional crops has on the decision to grow switchgrass. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. Lower levels of herbicide and fertilizer associated with switchgrass could have the positive attribute of making a lower impact on the environment through chemical pollution per acre than more chemically intensive row crops. The lower use of herbicides and fertilizers could represent lower input costs which might be attractive to producers. Therefore, LINPUT is hypothesized to have a positive effect on interest in growing switchgrass.

PLANCON is a variable representing the possible conflicts between the planting and harvesting period for switchgrass and the planting and harvesting period for other crops. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. If a producer sees that there could be a high potential for timing conflicts between switchgrass and other crops which may be more conventional and about the producer may be more knowledgeable, there may be less inclination to plant switchgrass as an energy crop. Because of this PLANCON is hypothesized to be negatively associated with interest in growing switchgrass.

CONLEASE is a variable that represents the producer's concerns about planting a perennial crop on land that is leased. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. Switchgrass is a perennial crop with a stand life of 10 years or more, which may cause issues with planting on land leased for less than that period of time. If a producer places a high importance on this issue, he or she may be less interested in growing switchgrass. Therefore, CONLEASE is hypothesized to be negatively associated with interest in growing switchgrass.

CONCAP is a variable that represents the importance that the producer places on the concern about having the financial and equipment resources needed to produce switchgrass. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. Switchgrass, as with any crop, requires financial investment. If a producer sees this issue as being highly important, he or she may show less interested in switchgrass production. Therefore, CONCAP is hypothesized to be negatively associated with interest in growing switchgrass.

DIVERSE is a variable that represents the importance that the producer places on the opportunity that switchgrass may allow them to diversify his or her farming operation. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. The opportunity to be a diversifying crop is hypothesized to be a positive attribute of switchgrass. The more importance the producer places on diversification, the more interest they may show in growing switchgrass. Because of this, it is hypothesized that DIVERSE will be positively associated with interest in growing switchgrass.

ENERENV is a variable that represents how much importance the producer places on switchgrass's possible ability to contribute to national energy and help the environment by producing switchgrass for fuel. These are hypothesized to be positive aspects of switchgrass production. Therefore, it is hypothesized that ENERENV will be positively associated with interest in growing switchgrass.

LAGPOT is a variable that represents the importance that the producer places on the three year lag between planting and switchgrass reaching its full yield potential. It has a value of one representing a high level of importance and a value of zero representing a low level of importance. The lag time between planting switchgrass and realizing the full potential of a switchgrass stand is one of the perceived drawbacks to planting switchgrass as an energy crop. If the producer sees this as important issue, he or she may be less interested in producing switchgrass for energy production. Because of this, it is hypothesized that LAGPOT will be negatively associated with interest in growing switchgrass.

COMPKNOW is a variable that represents the importance that the producer places on the comparison between his or her knowledge of switchgrass compared to other crops. Because switchgrass is a new crop, information regarding its production may not be as widely disseminated as other more conventional crop options. If a producer puts a high level of importance on the discrepancy between his or her knowledge of switchgrass compared to other crops, they may be less likely to be interested in growing switchgrass. Because of this, it is hypothesized that COMPKNOW will have a negative effect on interest in growing switchgrass.

SWEST, MIDS, and GULF are dummy variables that represent states in the southwest (OK, TX), mid-south (TN, KY, AR), and gulf regions respectively (LA, MS, AL). The omitted regional dummy represents the Atlantic states in the study region (GA, NC, SC, VA).

CRP and CRPACSHR are variables that describe the producer's Conservation Reserve Program situation. CRP is a dummy variable with a value of 1 if the producer currently has acres enrolled and a value of 0 if the producer does not. CRPACSHR is a variable that represents the percentage of farm acres that the producer has in the CRP program. It may be the case that a producer with land in the CRP program is more concerned about environmental preservation than one who does not. One perceived benefit of switchgrass is that it may be less harmful on the environment that traditional row crops, which could appeal to an environmentally conscious producer. Hence, CRP is hypothesized to have a positive effect on interest in switchgrass. Because of the length of CRP contracts, land that is currently in CRP may be locked as such for several years in the future. The higher the percentage of land in CRP, the less percentage of land there is free to be converted to other uses, such as planting switchgrass. Because of this, CRPACSHR is hypothesized to have a negative effect on the acre share of switchgrass converted.

IDLED and IDLESHR are variables that deal with acres of land a producer has that have been left idled. IDLED is a dummy variable that has a value of 1 if the producer has any farm acres that have been left idled and a value of 0 if the producer does not. Land that has been left idled may have been utilized in that way because factors such as available soil nutrients, water availability, or erosion issues have prevented it from being used for conventional farming activities. Because switchgrass is a potential crop that has the ability to grow on marginal lands (Lewandowski et al. 2003) with the ability to help prevent erosion (Ellis 2006), any acreage that is idled due to poor yield or erosion problems with conventional crops could be productive under the cultivation of switchgrass. Therefore, IDLED is hypothesized to have a positive effect on producer interest in switchgrass and IDLESHR is expected to have a positive effect on the share of acres planted to switchgrass.

COMCON is a dummy variable that indicates if the producer has ever produced a commodity under contract. It has a value of 1 if the producer has produced a commodity under contract and a value of 0 if the producer has not. Contracts can be a way of reducing risk associated with uncertainty in prices and demand of a commodity. It is hypothesized that switchgrass may be sold primarily under contract and farmers who have experience dealing with contract sales may be more interested in growing switchgrass. However, it is possible that the producer has grown a commodity under contract and did not have a positive experience. This could lead to them being leery of doing so again. Because of this, it is hypothesized that COMCON will have a negative effect on the share of acres planted.

NOEROS is a dummy variable indicating whether or not the producer has significant erosion problems on his or she land. It has a value of 1 if the producer has significant erosion problems and 0 if the producer does not. One of the positive attributes of switchgrass production is that it has the potential to reduce erosion. If the farmer does not have erosion problems, he or she may be less likely to show interest in growing switchgrass. Therefore, it expected to have a positive influence on interest in growing switchgrass.

Off-farm income of the decision maker is a factor that has been analyzed by several adoption studies. Norris and Batie (1987) found off-farm income to have a negative effect on conservation practice expenditures and Fernandez-Cornejo, Hendricks, and Mishra (2005) found it to have a positive effect on adoption of integrated pest management practices. For this study, off-farm income will be analyzed using the variables OFIL10, OFI1030, and OFI3050. OFLI10 represents producers with less than 10,000 dollars in off-farm income in 2008, OFI1030 represents farmers with greater than 10,000 dollars but less than 30,000 dollars in off-farm income in 2008, and OFI3050 represents farmers with greater than 30,000 dollars but less than 50,000 dollars in off-farm income. Having a higher off-farm income could mean that the producer would have access to more capital to establish a switchgrass stand. Also, having a higher off-farm income could mean that the producer may be able to rely less on farm income and might therefore be willing to take more risk with his or her farming operation. for these reasons, OFIL10, OFI1030, and OFI3050 are hypothesized to have a positive effect on interest in growing switchgrass and the share of acres that the producer is willing to convert to switchgrass.

Data

"Switchgrass Production for Energy: Your Views" is the title of a mail survey conducted to collect data for use in estimating farmers' willingness to convert acreage to switchgrass. This survey will be the basis for the data analyzed in this study. For the survey, farmers with farms having at least $10,000 in sales were randomly selected by the National Agricultural Statistics Service from the following states: Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

The mail survey consisted of 39 questions and was sent out to 7,000 farmers. The questions were designed and selected to evaluate the influences of demographics, farm characteristics, and attitudes toward environmental issues. The five major areas addressed in the survey were 1) the respondent's knowledge of, and interest in, switchgrass as an energy crop; 2) the respondent's opinion on a number of topics related to switchgrass production as a biomass feedstock; 3) characteristics of the farm operation, including types of enterprises and use of various agricultural practices; 4) financial matters, including sources and extent of income; and 5) socio-demographic characteristics of the respondents.

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

Results

A total of 760 observations remained after rejecting observations with missing values for the variables used in the model. Of these remaining responses, 67.34% of the producers claimed to be at least somewhat interested in growing switchgrass as an energy crop. This percentage of interested respondents compares favorably with Jensen et al. (2007) which found that 29.6% of Tennessee respondents would be interested and Wen et al. (2009) which found that 43% of southern Virginian respondents would definitely be interested in growing switchgrass. Of these responses that showed interest in growing switchgrass (N=512), the average number of acres they would be willing to convert to switchgrass was 76.67, which equal to a 24.46% share of acres farmed for these respondents. This is a higher number in comparison to the findings of Wen et al. (2009) and Jensen et al. (2007), which were 66 average acres and 67.21 average acres converted per farm respectively.

Tobit Model with Sample Selection

As previously discussed, the dependant variables INTEREST and SWITSHR were estimated as a Tobit model with sample selection. The estimated coefficient for ρ (.0802) was statistically significant at α=.10, meaning that the model was significant overall compared to running separate Tobit and Probit models with the variables. A chi-squared test was also used to test the significance of the Tobit Model with Sample Selection compared to separate Tobit and Probit models. The log likelihood ratio (LLR) for the test was found using the following formula:

$$(16) \qquad LLR = 2 \times (TBS\ LLR - (Probit\ LLR + Tobit\ LLR)).$$

Using this formula, the LLR was computed to be 3.325. The chi-squared statistic for the .10 level of significance and one degree of freedom is 2.71, with the rejection region being to the right of this value. The LLR for this test falls in the rejection region, therefore the hypothesis that the two equations should be estimated separately should be rejected.

Probit Selection Equation for INTEREST

Farm and Farmer Variables

The coefficient for DECAGE is negative and statistically significant which suggest that older producers would be less likely to be interested in producing switchgrass. This corresponds with the findings of Daberkow and McBride (1998) and Norris and Batie (1987). Producers with beef cattle operations are less likely to be interested, as suggested by BEEF having a negative coefficient. Reluctance to adopt new production methods or crops before one sees them work for someone else appears to be a trait that lowers the likelihood of a producer being interested as evidenced by the variable RELUCTNE having a negative and significant coefficient. This corresponds to several other studies (e.g. Fernandez-Cornejo, Beach, and Huang 1994; Daberkow and Mcbride 1998; Fernandez-Cornejo, Daberkow, and McBride 2001) that found that early adopters of innovations tend to be less risk adverse than those that choose not to be early adopters. The estimated coefficient for the dummy variable MIDS was negative and significant, indicating that producers in the mid-south region are less likely to be interested in growing switchgrass than producers in the unobserved Atlantic region.

The coefficients for HAY1 and HAY2 were positive and significant suggesting that owning hay equipment and the combination of owning hay equipment and producing hay on one's farm make producers more likely to be interested. This corresponds with what Jensen et al. (2007) found with hay equipment having a statistically significant positive effect on the hectare share planted to switchgrass Likewise, the use of custom hay harvest services influences producers to be more likely to be interested. Not having significant erosion problems appears to lower a farmer's likelihood of being interested, as NOEROS has a negative and significant coefficient. The estimated coefficients for HACFARM, EDUCATIO, SWEST, GULF, IDLED, CRP, OFI1030, and OFI3050 were not significantly different than zero.

Opinion Variables

As expected PLANCON, CONLEASE, and CONCAP all had coefficients that were significant and negative, suggesting that these factors negatively impact a producer's likelihood of being interested. LINPUT, DIVERSE, and ENERENV also had expected results with coefficients that were significant and positive, suggesting that these factors negatively impact a producer's likelihood of being interested. The dummy variable representing the lowest level of off-farm incomes, OFIL10, is negative and significant, indicating that producers with off-farm incomes less than 10,000 dollars are less likely to be interested in growing switchgrass than a producer with the omitted off-farm income of 50,000 dollars or more. This corresponds with the findings of Fernandez-Cornejo, Handricks, and Mishra (2005) that producers with a higher off-farm income are more likely to be early adopters of innovation. The estimated coefficients for COMCON, LAGPOT, and COMPKNOW were not significantly different than zero.

Tobit Regression for the Share of Acres Producers are Willing to Convert to Switchgrass

The estimated coefficient for PRICE is positive and significant, showing that producers in the study may be price responsive. Contrary to what was hypothesized, the estimated coefficient for HACFARM is negative and significant, indicating that larger farms are willing to devote a lower percentage of acreage to the production of switchgrass than smaller farms. The estimated coefficient for DECAGE is positive and significant, indicating that older producers are willing to devote a lower percentage of acreage to the production of switchgrass than smaller farms. The estimated coefficient for SWEST and GULF is positive and significant, indicating that producers in these regions are willing to devote a higher percentage of acreage to the production of switchgrass than producers in the Atlantic region. The reluctance to adopt new production methods or crops before one sees them work for someone else appears to have a negative effect on the share of acres a producer is willing to switchgrass, as evidenced by the coefficient for RELUCTNE being negative and significant.

The estimated coefficient for COMCON is negative and significant, indicating that producers that have previously produced commodities under contract are likely to devote a smaller percentage of acreage to the production of switchgrass than producers that have not produced commodities under switchgrass. The coefficient for HAY3 is negative and significant, which is contrary to what was hypothesized, indicating that producing hay while not currently own hay harvesting equipment has a negative effect on the share of acres a producer is willing to devote to switchgrass. The estimated coefficient for CRPACSHR is negative and significant, indicating that farms with larger acre shares of CRP land are likely to devote a lower percentage of acreage to the production of switchgrass.

Conclusions

The results of this study have several possible implications for switchgrass production and adoption expansion efforts in the southeastern United States. Based on the results, individuals and organizations that want to promote interest in adopting switchgrass may want to emphasize switchgrass' positive attributes, such as its potential for lowering input requirements, its ability to diversify a producer's crop mix, and the possibility of it contributing to the nation's energy security and environment. Also, farmers that have erosion problems on their land showed higher interest in switchgrass production, which means that switchgrass' ability to reduce erosion compared to more traditional crops could be emphasized as well. Concerns that affect producers' interest in growing switchgrass that likely need to be addressed through educational programs include management techniques to deal with possible conflicts between the planting and harvesting of switchgrass and other crops, contract arrangements that enable planting of switchgrass on land that is leased, and efficient use of financial and equipment resources needed to produce switchgrass.

From the results, it can be concluded that older producers would be less interested in switchgrass production, as they may not continue farming long enough to see the full benefits of a switchgrass stand. Those producers that operate a beef cattle operation are likely to be less interested, as well. This may be due to the reluctance of these producers to convert acres of pasture to switchgrass production and seems to indicate that areas with a high percentage of beef cattle farmers may not be an ideal switchgrass production area. Contrarily, producers that own hay equipment or have used custom hay harvest service may be more likely to be interested in growing switchgrass.   Hence, switchgrass may be first adopted by producers who already have equipment that may be helpful in growing switchgrass.

The results of this study indicate that the share of acres that would be converted to switchgrass will be less on a larger farm. Also, while older farmers may be less willing to adopt switchgrass, those that do may be willing to devote more acreage that a younger farmer. This indicates that areas with smaller farms and younger farmers, on average, may show more acres being converted to switchgrass, ceteris paribus. Those producers who are reluctant to adopt a new crop before they see it work for others reasonably may show less interest in producing switchgrass and if they are willing to adopt, will likely convert a smaller share of acreage to switchgrass. Producers with a higher percentage of acreage devoted to CRP land may show a likelihood of devoting a smaller share of acres to switchgrass, which indicates that areas with producers that have a higher portion of their land devoted to CRP may devote a smaller portion of acres to switchgrass.   This result suggests that CRP rules may need to be modified to encourage switchgrass production in a sustainable way on CRP lands. The results show that producers are sensitive to price with respect to both adopting switchgrass and the share of acres they would be willing to convert, indicating that a higher price offered at the plant gate should mean that a bio-refinery will receive more biomass.

This study has given new information about switchgrass production from the producer's prospective in the southeastern U. S. However, there is still a substantial lack of knowledge in related areas, such as contract preferences or harvesting and storage arrangements, that future studies can build upon.

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Appendix A: Tables

Table A.1. Farm and farmer demographics for the sample.

Characteristics	Census Averages	Survey Respondent Percentages
Net Farm Income Before Taxes		
Negative (Less than $0)		16.02%
$0 - $9,999	68.63% (< 9,999)	28.63%
$10,000 - $14,999		12.61%
$15,000 - $19,999		6.48%
$20,000 - $24,999	12.65%(10,000- 24,999)	5.43%
$25,000 - $29,999		4.90%
$30,000 - $34,999		3.50%
$35,000 - $39,999		2.28%
$40,000 - $44,999		2.01%
$45,000 - $49,999	6.18%(25,000- 49,999)	1.58%
$50,000 - $74,999		4.47%
$75,000 - $99,999	3.55%(50,000- 99,999)	2.89%
$100,000 - $149,999	8.98%(> 100,000)	3.77%
At least $150,000		5.43%
		(N=1142)
Net Off-farm Income Before Taxes		
Negative (Less than $0)	-	5.8%
$0 - $9,999	-	7.52%
$10,000 - $14,999	-	4.71%
$15,000 - $19,999	-	2.90%
$20,000 - $24,999	-	3.53%
$25,000 - $29,999	-	4.98%
$30,000 - $34,999	-	4.80%
$35,000 - $39,999	-	4.71%
$40,000 - $44,999	-	5.34%
$45,000 - $49,999	-	6.25%
$50,000 - $74,999	-	17.3%
$75,000 - $99,999	-	11.87%
$100,000 - $149,999	-	9.60%
At least $150,000	-	10.69%
		(N=1104)
Education Level Obtained:		
Elementary/Middle school	-	1.91%
Some high school	-	3.03%
High school	-	29.19%
Some college	-	24.32%
College graduate	-	26.63%
Post graduate	-	14.91%
		(N=1254)

Table A.2. Farm and farmer demographics for the sample cont.

Characteristics	Census Average	Survey Respondent Percentages
Total Acres:		**Mean**
Acres owned	318.82 acres	240.59 acres
Acres rented	-	131.62 acres
Acres rented to others	-	194.68 acres
Total acres farmed	-	384.21 acres
Age of Operator	58.0	60.28 years
Farming Experience	-	35.3 years

Table A.3. Familiarity and interest in growing switchgrass as an energy crop.

Interest in Growing Switchgrass as an Energy Crop	**Familiarity with switchgrass as a crop to be used in energy production (Percent)**		
	Not at all familiar (N=631)	Somewhat familiar (N=434)	Very familiar (N=33)
Not at all interested (N=437)	50.7	25.1	24.2
Somewhat interested (N=479)	38.4	52.0	33.3
Very interested (N=182)	10.9	22.8	42.4

Table A.4. Farmer characteristics.

Characteristic	All Survey Respondents	Not at all Interested Respondents	Somewhat Interested Respondents	Very Interested Respondents
		Percent		
Owns a personal computer	74.22 (N=1253)	63.1 (N=471)	80.2 (N=531)	85.23 (N=210)
Extension workshops attended in 2008	1.1 (avg. events) (N=1195)	0.91(avg. events) (N=485)	1.2 (avg. events) (N=545)	1.29 (avg. events) (N=203)
Age	85 (N=1284)	82 (N=468)	87.2 (N=530)	87.5 (N=208)
Farming Experience	60.3 (avg. years) (N=1241)	63.8 (avg. years) (N=504)	58.6 (avg. years) (N=529)	56.3 (avg. years) (N=208)
Produced commodity under contract before	21.8 (N=1222)	13.7 (N=497)	25 (N=519)	33 (N=206)
Currently belongs to the following organizations :				
Grower/ commodity	13.9 (N=1169)	11 (N=483)	13.2 (N=491)	22.5 (N=195)
Cooperative	31.8 (N=1170)	30.8 (N=483)	32.3 (N=492)	33.3 (N=195)
Farm Bureau	57.7 (N=1172)	56.8 (N=484)	57.4 (N=493	60.5 (N=197)
Hunting-related	21.6 (N=1169)	17.8 (N=483)	23 (N=491)	27.7 (N=195)
Environmental	8.7 (N=1169)	5.4 (N=483)	9.8 (N=491)	14.4 (N=195)

Table A.5. Hay equipment demographics.

	All Survey Respondents	Not at all interested Respondents	Somewhat interested respondents	Very Interested Respondents
		Percent		
Owns Hay Equipment	61.5 (N=1235)	55.1 (N=501)	65.7 (N=525)	66.5 (N=209)
Used Custom Hay Services	21.6 (N=1210)	20.6 (N=495)	21.6 (N=515)	24 (N=200)

TableA.6. Farmer concerns about risk and loss.

	All Survey Respondents	Not at all interested Respondents	Somewhat interested respondents	Very Interested Respondents
Average responses from one to five with one being strongly disagree and 5 being strongly agree				
You are the type of farmer who is more willing to take financial risks than others	2.7 (N=1176)	2.5 (N=457)	2.7 (N=513)	3.2 (N=206)
You must be willing to take substantial financial risk to be a successful farmer	3.1 (N=1178)	3.0 (N=459)	3.1 (N=512)	3.3 (N=207)
You are reluctant about adopting new production methods or crops until you see them working for others	3.1 (N=1184)	3.4 (N=464)	3.1 (N=517)	2.5 (N=203)
You are more concerned about a large loss to your farming operation than about missing a substantial gain	3.4 (N=1177)	3.42 (N=459)	3.5 (N=515)	3.2 (N=203)

Table A.7. Farm organization.

	All Survey Respondents	Not at all interested Respondents	Somewhat interested respondents	Very Interested Respondents
		Percent		
Description of farm operation				
Children or Grandchildren will inherit farm	58.54 (N=1182)	52.4 (N=479)	60 (N=503)	69.5 (N=200)
Land sold for development after farmer ceases	7.9 (N=1182)	9.2 (N=479)	7.8 (N=503)	5 (N=200)
Land will be sold or leased to other farmer after farmer ceases farming	20.7 (N=1182)	23.8 (N=479)	20.5 (N=503)	14 (N=200)
Other plans	12.9 (N=1182)	14.6 (N=479)	11.7 (N=503)	11.5 (N=200)
Livestock present on farm	80 (N=1208)	78.8 (N=505)	80.7 (N=498)	75 (N=205)
Farm Decisions				
Farm alone makes decisions	70.7 (N=1244)	72.5 (N=498)	70.3 (N=536)	67.1 (N=210)
Shared decision with partners or family	26.2 (N=1244)	22.69 (N=498)	27.6 (N=536)	40 (N=210)
Someone else makes the decisions	3.1 (N=1244)	4.6 (N=498)	2.0 (N=536)	(N=210)
Which best describes farm business				
Sole Proprietorship	76.6 (N=1228)	78.2 (N=491)	76.2 (N=530)	73.9 (N=207)
Partnership	15.2 (N=1228)	12.8 (N=491)	16.6 (N=530)	17.4 (N=207)
Cooperative	.16 (N=1228)	.41 (N=491)	.19 (N=530)	0 (N=207)
Corporation	4.2 (N=1228)	3.5 (N=491)	2.1 (N=530)	5.3 (N=207)
Other	3.7 (N=1228)	5.1 (N=491)	2.6 (N=530)	3.4 (N=207)

Table A.8. Variable means and estimated values

Variable	Mean value (N=760)	Mean value (N=512)	Estimated sign
HACFARM	3.85	4.01	+
EDUCATIO	4.18	4.23	?
DECAGE	5.86	5.69	?
CUSTHAY	0.22	0.23	+
BEEF	0.70	0.66	-
COMCON	0.24	0.29	?
HAY1	0.51	0.52	+
HAY2	0.16	0.17	+
HAY3	0.10	0.10	+
RELUCTNE	3.06	2.91	-
GULF	0.23	0.22	?
MIDS	0.32	0.30	?
SWEST	0.14	0.13	?
OFIL10	0.11	0.09	-
OFI1030	0.15	0.15	-
OFI3050	0.22	0.21	-
PLANCON	2.44		-
CONLEASE	2.17		-
LINPUT	3.53		-
CONCAP	3.30		-
DIVERSE	3.00		+
ENERENV	3.25		+
LAGPOT	3.37		-
COMPKNOW	2.96		-
NOEROS	0.54		-
IDLED	0.13		+
CRP	0.15		+
PRICE		82.7	+
IDLESHR		0.03	+
CRPACSHR		0.08	-
RENTSHR		0.22	-

Table A.9. Estimated Tobit Model with Sample Selection

Variable	*INTEREST* (N1=760) Est. Coeff.	Std. Err.		Mean	*SWITSHR* (N2=512) Est. Coeff.	Std. Err.		Mean	Hyp. Sign
INTERCEPT	0.078	0.626			0.125	0.177			
HACFARM	-0.001	0.001		3.85	-0.048	0.012	***	4.01	+
EDUCATIO	-0.002	0.064		4.18	-0.006	0.018		4.23	?
DECAGE	-0.142	0.061	**	5.86	0.036	0.019	*	5.69	?
CUSTHAY	0.518	0.200	***	0.22	0.044	0.048		0.23	+
BEEF	-0.704	0.176	***	0.70	-0.008	0.041		0.66	-
COMCON	0.192	0.181		0.24	-0.096	0.046	**	0.29	?
HAY1	0.573	0.184	***	0.51	-0.036	0.052		0.52	+
HAY2	0.540	0.230	**	0.16	0.118	0.060	**	0.17	+
HAY3	0.199	0.284		0.10	-0.103	0.071		0.10	+
RELUCTNE	-0.112	0.064	*	3.06	-0.055	0.018	***	2.91	-
GULF	-0.220	0.190		0.23	0.141	0.052	***	0.22	?
MIDS	-0.321	0.180	*	0.32	0.057	0.051		0.30	?
SWEST	-0.273	0.238		0.14	0.118	0.063	*	0.13	?
OFIL10	-0.468	0.223	**	0.11	-0.069	0.075		0.09	-
OFI1030	-0.094	0.211		0.15	-0.081	0.054		0.15	-
OFI3050	-0.106	0.170		0.22	-0.070	0.051		0.21	-
PLANCON	-0.130	0.060	**	2.44					-
CONLEASE	-0.206	0.053	***	2.17					-
LINPUT	0.291	0.068	***	3.53					-
CONCAP	-0.146	0.066	**	3.30					-
DIVERSE	0.442	0.075	***	3.00					+
ENERENV	0.314	0.067	***	3.25					+
LAGPOT	0.043	0.069		3.37					-
COMPKNOW	-0.052	0.057		2.96					-
NOEROS	-0.251	0.141	*	0.54					-
IDLED	0.298	0.260		0.13					+
CRP	-0.071	0.205		0.15					+
PRICE					0.001	0.001	**	82.7	+
IDLESHR					0.023	0.145		0.03	+
CRPACSHR					-0.109	0.038	***	0.08	-
RENTSHR					0.019	0.058		0.22	-
σ	0.382	0.018	***						
ρ	-0.265	0.152	*						

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

Appendix B: Survey

Switchgrass Production for Energy: Your Views

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 confidential. Only summaries of the results will be presented. The survey should take you about 10 to 15 minutes to complete.

About Switchgrass

1. How familiar are you with switchgrass as a crop to be used in energy production? (Circle the answer)

Not at all familiar (Skip to question 3)	Somewhat familiar (Continue to question 2)	Very familiar (Continue to question 2)

2. From which of the following sources have you obtained information on switchgrass? (Check one box for each information source)

Yes	No	
☐	☐	Farmer or commodity magazines
☐	☐	Other mass media (Internet, radio, TV, newspapers, magazines)
☐	☐	Extension Service
☐	☐	University research stations or other university sources
☐	☐	Federal agricultural agency (for example USDA, NRCS, FSA)
☐	☐	State agricultural agency
☐	☐	Farmer or commodity organizations
☐	☐	Other farmers, friends, or neighbors
☐	☐	Private firms
☐	☐	Other (Please describe: ____)

3. Please read through the following factors and circle how important each might be in influencing your decision to grow switchgrass (circle the number indicating the importance of each factor).

Factors	Importance Level

	Not at All	Not Very	Some-what	Very	Extre-mely
Possible conflicts between planting/harvest period for switchgrass and planting/harvest period for your other crops	1	2	3	4	5
Concern that the market for switchgrass as an energy crop is not developed enough yet	1	2	3	4	5
Profitability of growing switchgrass compared with other farming alternatives	1	2	3	4	5
Possibility that you will cease farming in the next few years due to retirement or other reasons	1	2	3	4	5
Your knowledge about growing switchgrass compared with your knowledge about growing other crops	1	2	3	4	5
Concern about planting a perennial crop such as switchgrass on land that is leased	1	2	3	4	5
Opportunity to diversify your farming operation	1	2	3	4	5
Potential for creating jobs in your community	1	2	3	4	5
Potential for switchgrass to reduce erosion on your farm	1	2	3	4	5
Whether acreage converted to switchgrass would qualify for CRP payments or not	1	2	3	4	5
Potential for switchgrass to provide habitat for native wildlife on your farm	1	2	3	4	5
Potential to contribute to national energy security by producing switchgrass for fuel	1	2	3	4	5
Potential to help the environment by producing switchgrass for fuel	1	2	3	4	5
Ability to use switchgrass as a feed for livestock	1	2	3	4	5
The three year lag between planting and switchgrass reaching its full yield potential	1	2	3	4	5
Possibility of lowering fertilizer and herbicide applications as compared with crops currently growing	1	2	3	4	5
Concern about having the financial and equipment resources needed to produce switchgrass	1	2	3	4	5
Other (Please describe: ______________________________)					

4. How interested are you in growing switchgrass as a crop to be used for energy production? (Circle the answer)

Not at all interested	Somewhat interested	Very interested

If you indicated you were **NOT at all interested** in growing switchgrass in question 4, please skip to question 12. If you indicated **some interest** in growing switchgrass in question 4, please continue on to question 5.

Projected Yields for Switchgrass

Area	**Tons/ Acre**
Alabama	5.1
Arkansas	5.1
Georgia	5.2
Kentucky	5.3
Louisiana	5.3
Mississippi	5.3
North Carolina	3.8
E. Oklahoma	4.5
W. Oklahoma	2.9
South Carolina	4.8
Tennessee	6.0
E. Texas	3.9
Western Texas	3.7
Virginia	4.9

5. Annual switchgrass yields in your area are listed in the table to the left. Assume you are responsible for harvesting costs and all inputs, except seed, which is provided by the contractor.

Would you be willing to sell switchgrass at a price of **$100/ton** if the switchgrass is picked up at your farm at the time of harvest? (Check one box and fill in the blank)

☐ No, and the reason(s) are ______________________

____

☐ Yes and I would be willing to produce ________ acres

What are the current uses of the land you would convert (for example type of crop, pasture, idle, CRP, timber, or other)? If some of the land would be newly rented land, please list as "new rented acres".

Type of crop or other use (ex: pasture, idle, CRP, forest, etc.)	Number of acres to be converted
a. ______________________________	____________
b. ______________________________	____________
c. ______________________________	____________
d. ______________________________	____________
e. ______________________________	____________
Total acres converted to switchgrass =	____________

6. Would you be willing to sell at $70/ton if harvest services were provided?

☐ Yes ☐ No, and the reason(s) are ______________________________

7. Would you prefer to grow switchgrass under a contract? (Check one box and fill in the blank)

☐ Yes, and the contract length would need to be _______ years

☐ No

8. If you were to grow switchgrass, would you be willing to store it on your farm after harvest if you were reasonably compensated for the costs? (Check one box)

☐ Yes ☐ No, and the reason(s) are ________________________________
____
(Skip to question 11)

9. If you were willing to store switchgrass on your farm, and the switchgrass was harvested in December, how long would you be willing to store it? _______ days

10. Which best describes your storage situation (Check one box)

☐ You have an existing hay shed or barn where the switchgrass could be stored

You can store about _______ number bales of hay in this barn. Indicate bale type with a check mark.

_______ large square
_______ small square
_______ large round
other

☐ You would construct storage facilities (such as a gravel pad with tarp for cover)

☐ Other (Please describe:____)

11. Would you be interested in participating in a cooperative that harvests, transports, stores, and markets switchgrass? (Check one box)

☐ Yes ☐ No, and the reason(s) are ___________________________________

About Your Farming Operation

12. How many acres did you farm in 2008 that you (Fill in the blanks):

Owned ________ acres
Rented ________ acres (rent paid was $_______/acre and the lease was for _____ years)
Other ________ acres (farmed but neither owned nor rented these acres)

Total________acres farmed in 2008 (total = owned + rented + other)

13. Did you own additional farmland that you rented to someone else in 2008? (Check one box)

14. If you ☐ Yes ☐ No (Skip to question 15) rented farmland to someone else,

a) How many acres did you rent to someone else? _______ acres

b) How much rent (per acre) did you charge? $_______/acre

c) What was the length of the lease? _______ year(s)

15. How many acres of each crop/product did you grow in 2008? (Fill in the blanks)

Soybeans	______ acres	Fruit	______ acres
Cotton	______ acres	Vegetables	______ acres
Tobacco	______ acres	Corn	______ acres
Wheat	______ acres	Pasture	______ acres
Alfalfa Hay	______ acres	Other Hay	______ (Describe: ______________________)
Timber	______ acres	Idle	______ acres
Other Uses	______ acres (Describe:______________________________)		

16. Which of the following best describes your farm's current situation? (Check one box)

☐ Currently have a Conservation Compliance Plan (CCP)

☐ Not required to have a CCP but practice erosion control methods

☐ Significant erosion problems but erosion control practices not currently used

☐ No significant erosion problem on farmland

17. Do you have any acres enrolled in the Conservation Reserve Program (CRP)? (Check one box)

☐ Yes ☐ No (Skip to question 19)

18. If you have acres enrolled in the CRP program (fill in the blank)

Grass? __________ acres Trees? __________ acres

19. Do you own any hay equipment? (Check one box)

☐ Yes ☐ No (Skip to question 21)

20. What types of hay equipment do you own? (For each type of equipment, check one box, then fill in the blanks)

Yes	No		
☐	☐	Mower	
☐	☐	Rake	
☐	☐	Round Baler	bale size________________
☐	☐	Small Square Baler	bale size________________
☐	☐	Large Square Baler	bale size________________
☐	☐	Other (Please describe: ____________________________)	

21. Did you use custom hay harvest services in 2008? (Check one box)

☐ Yes ☐ No (Skip to question 23)

22. If you used custom hay harvest services in 2008, indicate the costs per acre.(Fill in the blanks)

Mowing/raking	$________/acre	Baling for small square bales	$________/bale
Baling for round bales	$________/bale	Baling for large square bales	$________/bale

23. Do you currently use no-till production methods? (Check one box)

☐ Yes ☐ No

24. Do you have any of the following types of livestock operations? (For each type of livestock operation, check one box)

Yes	No		Yes	No	
☐	☐	Beef cow-calf	☐	☐	Hogs
☐	☐	Backgrounding/stockering	☐	☐	Horses
☐	☐	Dairy cattle	☐	☐	Other (Please describe: ______________ ______________________________)
☐	☐	Poultry			

25. Which of the following best describes your farming operation? (Check one box)

☐ One or more of your children or grandchildren will farm your land after you

☐ Your land will be sold for development after you cease farming

- [ ] Your land will be sold or leased to another farmer after you cease farming
- [ ] Other (Please describe: ____)

26. Which of the following best describes your role in deciding which crops to grow on your farm? (Check one box)

- [ ] I make the decision on my own
- [ ] I share the decision making with partners or family
- [ ] Someone else makes this decision

27. Which of the following best describes your farming business? (Check one box)

- [ ] Sole proprietorship
- [ ] A partnership
- [ ] A cooperative
- [ ] A corporation
- [ ] Other (Please describe: ____)

28. Which of the following describes your farming operation's net income from farming in 2008 (before taxes)?(Check one box)

☐ Negative (less than $0)	☐ $25,000-$29,999	☐ $50,000-$74,999
☐ $0-$9,999	☐ $30,000-$34,999	☐ $75,000-$99,999
☐ $10,000-$14,999	☐ $35,000-$39,999	☐ $100,000-$149,999
☐ $15,000-$19,999	☐ $40,000-44,999	☐ At least $150,000
☐ $20,000-$24,999	☐ $45,000-49,999	

29. For every $100 of farm assets your farming operation has, how many dollars are financed with debt? (Check one box)

☐ $0	☐ $5-$9.99	☐ $15-$19.99	☐ $40-$69.99
☐ $1-$4.99	☐ $10-$14.99	☐ $20-$39.99	☐ greater than $70

30. Have you ever produced any commodity under contract? (Check one box)

☐ Yes ☐ No

About You

31. Your age in years__________ Your years of experience farming _________

32. Do you own a personal computer?(Check one box) ☐ Yes ☐ No

33. How many extension workshops or experiment station field days did you attend in 2008? (Fill in the blank) ________

34. What is the highest education level you have attained? (Check one box)

☐ Elementary/Middle school ☐ High school ☐ College graduate
☐ Some high school ☐ Some College ☐ Post graduate

35. What was your household's 2008 net income (before taxes) from off-farm sources?

☐ Negative (less than $0) ☐ $25,000-$29,999 ☐ $50,000-$74,999
☐ $0-$9,999 ☐ $30,000-$34,999 ☐ $75,000-$99,999
☐ $10,000-$14,999 ☐ $35,000-$39,999 ☐ $100,000-$149,999
☐ $15,000-$19,999 ☐ $40,000-44,999 ☐ At least $150,000
☐ $20,000-$24,999 ☐ $45,000-49,999

36. Please circle the answers that reflect your level of agreement with each of the following statements.

Statement	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
You are the kind of farmer who is more willing to take financial risks than others	1	2	3	4	5
You must be willing to take substantial financial risks to be a successful farmer	1	2	3	4	5
You are reluctant about adopting new production methods or crops until you see them working for others	1	2	3	4	5
You are more concerned about a large loss to your farming operation than about missing a substantial gain	1	2	3	4	5

Part 3: AN EXCEL SPREADSHEET-BASED DECISION TOOL FOR POTIENTIAL SWITHGRASS PRODUCERS

Introduction

Due to factors such as dependence on foreign oil and environmental concerns, there have been government policy initiatives dealing with alternative fuels that have far reaching impacts on the United States and world economies. An example of this type of policy is the Energy Independence and Security Act (EISA) of 2007, with its key provision being the Renewable Fuel Standard (RFS). The RFS has generated increased research into biomass production by mandating that by at least 36 billion gallons of ethanol for fuel be produced in the United States by 2022, with at least 16 billion gallons being ethanol that is derived from cellulose, hemi-cellulose, or lignin (U.S. Congress 2007).

Biomass accounts for over 3 percent of the energy consumed domestically and is currently the only source for liquid renewable fuels used in transportation (Perlack et al. 2005). There are many sources of biomass that can be used to make solid, liquid, and gaseous fuels including woody plants and their associated manufacturing waste and residues, aquatic plants, biological waste, and herbaceous plants such as grasses (Mckendry 2001). Biomass is promising because it allows us to take advantage of energy from the sun in a way that is compatible with current technologies and can be stored without technical problems allowing its energy to be used when needed and it could prove to be a clean energy source as the carbon that it releases during combustion is obtained from the atmosphere, potentially making it carbon neutral.

Generating sufficient biomass to meet the EISA’s 16 billion gallon cellulosic ethanol quota will require the production of dedicated energy crops. Switchgrass (*Panicum virgatum*) is among the species of herbaceous plants being considered to help meet the expected demand generated for biomass. Switchgrass is a warm season perennial grass. The perennial nature of switchgrass separates it from more conventional annual crops because it does not have fixed annual establishment requirements. Its native habitat includes the prairies, open ground and wooded areas, marshes, and pinewoods of much of North America east of the Rocky Mountains (Stubbendieck et al. 1991). There are two distinct geographic varieties or ecotypes of switchgrass, lowland and highland (Porter 1966; Brunken and Estes 1975). Lowland types can be found on flood plains and other areas that may be subject to flooding and upland types can typically be found in areas that have a low potential to flood (Vogel 2004). Lowland types tend to be taller, coarser, and show the ability to grow more rapidly than upland types (Vogel 2004).

Many benefits could be seen through the planting of switchgrass as a biomass feedstock for fuel. Because it is a native species, it also has a natural tolerance to pest and diseases and can be grown successfully throughout a large portion of the United States with minimal fertilizer applications (Jensen et al. 2007), which would be cost efficient and less disruptive to the surrounding environment. Switchgrass has the capability to show high yields on soil that, due to low availability of nutrients or water, would not lend itself to the cultivation of conventional crops (Lewandowski et al. 2003) which means that the grass could add utility to land that may not be economically useful otherwise. It has the positive attribute of reducing erosion due to its extensive root system and canopy cover (Ellis 2006) and shows the potential ability to reduce the buildup of CO_2 by being a feedstock for a cleaner burning fuel than fossil fuels and through soil carbon sequestration due it is being a deep rooted crop (Ma et al.2000).

Despite these possible benefits that could be realized from the implementation of switchgrass as a dedicated energy crop, there are hurdles to overcome. One of the draw backs associated with switchgrass being produced for biomass used in energy production, being an innovative practice, is that there is unfamiliarity associated with the specific costs of its production. The decision of a farmer to adopt an innovation is based on its perceived ability to provide more utility than other viable options which may be more conventional and whose associated risk may be more known and understood. Because of this, the distribution of knowledge related to the innovation, which for this study is the costs associated with the production of switchgrass, becomes imperative to the adoption of the practice. A productive way to disseminate this information in a manner that is readily understandable and adjustable to fit each individual farmer's operation is to apply it to a production decision tool in an excel workbook.

Objective

The objective of this paper is to explicate and present an interactive and adjustable excel spreadsheet-based decision tool for potential switchgrass producers that provides the user with detailed information on the costs incurred in each stage of a switchgrass operation in each year of its duration, which, for the purposes of this analysis, will be 10 years. The budget workbook is broken down into 13 different worksheets, including:

- welcome worksheet
- tutorial worksheet
- input-output worksheet
- cash flow worksheet
- cost distribution worksheet
- yearly cash flow worksheet
- accumulated cash flow
- planting and establishment worksheet

- stand maintenance worksheet
- harvest worksheet
- transportation worksheet
- storage worksheet
- biomass harvested worksheet

In the following chapters, the purpose of each worksheet, the source of the estimated figures in their adjustable cells, and the methods used in their calculating cells will be explained.

Literature Review

A significant portion of literature relating to switchgrass concerns the economic aspects of its production and delivery to a bio-refinery for the purpose of creating bio-energy. Many of these studies are regionally (e.g. Cundiff and Marsh 1996; Epplin 1996; Larson et al. 2010a; Larson et. al 2010b) or state (e.g. Sladden, Bransby, and Aiken 1991; Popp 2007) specific due to the variation in suitability of the crop and the focus on biomass production for alternative fuels in the area. Other studies focus on analyzing the cost of using switchgrass as a cellulosic biomass feedstock in comparison to other possible grass species options (e.g. Haque et al. 2008; Wilkes 2007). The results from these studies and others like them provide information used to compose budgets like those that create the foundation of this study.

Larson et al. (2010a), Larson et al. (2010b), Wang et al. (2009a), and Wang et al. (2009b) are examples of studies that consider the storage cost, among other costs, and biomass losses for different periods of storage time and methods. The data used in these studies came from a switchgrass harvest and storage study at the Milan Research and Education Center in Milan, Tennessee (English et al. 2008). The study analyzed many different storage options including whether the bails were round or square, if they were placed on bare ground or on a wooden pallet, the amount of time the bales were stored, and whether or not the bales were covered with a tarp. This data has been eminently valuable to this study by providing a base useable to calculate an estimate of the cost of storage given the type of bale used and the storage method as well as the loss in biomass given the duration of storage.

Fulton (2010) is a study that evaluated the impacts that introducing cellulosic ethanol plants in east Tennessee and west Tennessee would have on the economies of these two regions. In doing this, the study analyzed the costs of transporting the switchgrass from the farm to the bio-refinery. This information has been valuable in assembling the transportation cost section of this study.

The Woody Biomass Program ran by the College of Environmental Science and Forestry (ESF) at the State University of New York (SUNY) in 2008 created a Microsoft Excel based production decision tool for growing willow (Genus: *Salix*) for biomass energy production called "EcoWillow". This willow decision tool assumed planting on marginal soils with low labor, machinery, fertilizer, and herbicide inputs compared to traditional crops. It details the costs associated with willow establishment, stand maintenance, harvesting, and the transportation of the biomass. It can have a stand life of 11 or 22 years, depending on which the user chooses. While it is useful in determining total cost estimates, it lacks the ability to estimate the cost of storage and the amount of biomass dry matter loss during storage, both of which can factor prominently in estimating whether or not a switchgrass stand will be a fortuitous endeavor.

Bransby et al. (2005) is a study that used Microsoft Excel to model a switchgrass budget. It allowed for alternative producing, harvesting, handling, and transporting methods. Similar to the Eco-Willow program created by the Woody Biomass Program at SUNY, it lacks the ability to calculate and account for the cost of and dry matter loss during storage.

For any business activity, an estimated budget is needed before it is started and there are multiple examples of budgets dealing with switchgrass operations (Wilkes 2007; Green and Benson 2008; UT Extension 2009; UT Extension 2007). Green and Benson (2008) is a budget put together at North Carolina State University that gives the same values for the revenues and costs for each year of a switchgrass project. It mentions all important costs but lacks specificity with some of the more detailed expenses. Wilkes (2007) is a budget made for the Natural Resources Conservation Service Plant Materials Program. It estimates different costs associated with the establishment and subsequent years, with the subsequent years having the same costs projections. Because it covers three other grass budgets, it was not a relatively in depth analysis of switchgrass. The University of Tennessee Extension budget (2007) and (2009) serve as guidelines for establishing a switchgrass stand and up to ten years afterward. Most of the recommended values for input cost in this study have been drawn from these budgets.

Case Study

For illustrative purposes, the figures in this study will represent a specific case. This case will assume a 50 acre switchgrass stand with a mature yield of 6 dry tons of biomass per acre and that the producer will receive 75 dollars per dry ton at the plant gate. The biomass will be stored on farm for 200 days as round bales on pallets covered with a tarp. All other values to be used for the case study will be the suggested University of Tennessee Extension Budget values.

Methods

Input – Output Sheet

The input-output worksheet is the most integral worksheet in this excel workbook. It ties together the values from all of the other sheets in a way that is understandable to the user and has macros buttons that direct the user to each respective page. The two input sections of the worksheet are general data and startup loans. The output sections are financial analysis tools, production costs, and revenues and earnings.

Input Section

The general data section (Figure 1.) has six cells where the user can insert specific data. The interest rate for this workbook is determined in this section. The suggested interest rate is the current thirty year Treasury bond; however, the user has the ability to input any desired rate, as interest rates tend to fluctuate daily.

In this section, the user can input the cost of land, which includes taxes, leasing fees, and insurance. Internal administration fees are to be included in this section, as well. There are cells in this section that allow the user to include total acreage incentive payments they may receive from government agencies or any other organization and their duration. The last cell in this section gives the user the ability to insert the current price per dry ton of switchgrass at the plant gate. The suggested price per ton is $75.00 USD.

The startup loan section (Figure 1.) contains information regarding any loans that are taken out to establish the switchgrass stand. The three pieces of information to input are available equity, the amount of the loan, and the interest rate. This information will be used to determine the loan payments per period, assuming the loan is paid off over the life of the project which, in this case, is 10 years as according to Qin et al. (2006).

Josh's Switchgrass Project

Input and Output

Input data

General Data			
interest rate	%	3.47%	
Project size	acres	50	
Project life	yrs	10	10
Land costs (tax, lease) and insurance	$/acre/yr	0	0
Internal administration costs	$/acre/yr	0	0
Acreage Incentive payments	$/acre/yr	0	0
Total years of acreage incentive payment	yrs	0	0
Biomass price at plant gate	$/ton	75	75

Startup loans		
Available equity	$	
Loan amount		0
Loan interest rate	%	0%

Yellow cells: insert numbers, insert "0" if not applicable

Grey cells: output from previous inputs

Figure 1. The input section of the input-output sheet.

Output Section

The financial analysis tools section (figure 2.) gives output that aides the user in understanding how the revenues and costs relate to each other over the life of the project. The analysis includes net present value with realistic revenues and costs, net present value with optimistic (+10% revenue and -10% costs) revenues and costs, net present value (NPV) with pessimistic (-10% revenue and +10% costs) revenues and costs, and also gives the internal rate of return (IRR). The formula for NPV following Ross, Westerfield, and Jaffe (2002) is as follows:

$$(17) \qquad NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

Where C_0 is initial costs, T is the number of time periods of the project, t is each time period, r is the discount rate, and C_t is the cash flow for each time period. The net present values give the user an idea as to what the investment is worth in current terms after discounting each year's earnings back to the current period given that the project could go as planned, better than planned, or worse than planned. The IRR is the r where

$$(18) \qquad NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} = 0.$$

Basically, the IRR is the rate of return of a project where the NPV of the project is equal to zero.

The production costs, revenues, and earnings section (Figure 2.), like the financial analysis tools section, is meant to aid the user in understanding the revenues and costs associated with the project. This section contains average costs per acre, average gross revenue per acre, average profit per acre, average revenue per ton, average costs per ton, and average earning per ton. All of these reflect the average values over the total life of the project.

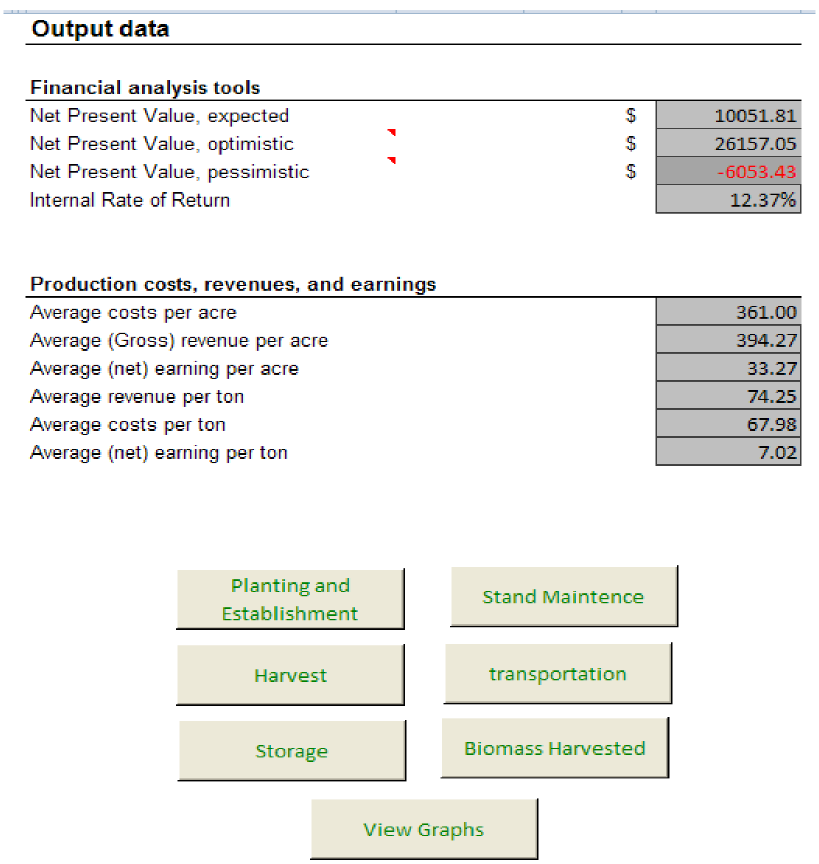


Figure 2. The output section of the input-output sheet.

Cash Flow Sheet

The cash flow worksheet documents the revenues and the expenditures for each year over the life of the operation. It shows the total and per acre and per acre revenues and expenditures in two separate diagrams. The expenditures per year include the following categories: land cost and insurance, administration cost, planting and establishment cost, storage cost, stand maintenance cost, harvest cost, and transportation cost. Planting and establishment costs apply only to the first year of the project while stand maintenance, which includes the cost of reseeding applies to years 2 through 9. Included in the revenues section is the amount of money received for the biomass and any sort of acreage incentive payments that the user might stand to receive. Finally, expenditures are subtracted from revenues to calculate profit before the subtraction of loans, labeled "Total Profit 1" in the table.

To put this in equation form,

(19) $$\text{TotalProfit 1} = \text{Totalrevenues} - \text{Totalexpenditures excluding loan payments.}$$

In the other cost section, loan payments are calculated and subsequently subtracted from Total Profit 1 to get profit after loan payments, which is labeled "Total Profit 2". In equation form, this is

(20) Total Profit 2= Total Profit 1 – loan payments

Total Profit 2 is then discounted back to the current time period for every year. This discounting is done for the realistic revenues and costs values, the pessimistic values, and the optimistic values. Total Profit 2 is also accumulated over each subsequent year for the realistic revenues and costs values, the pessimistic values, and the optimistic values.

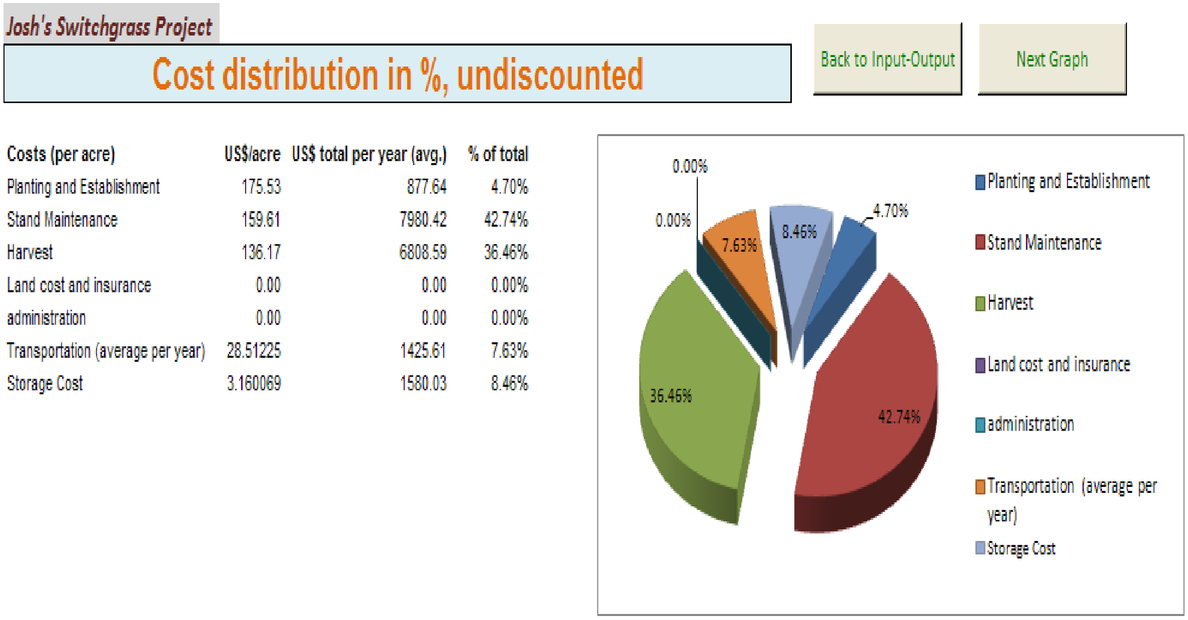
Cash Flow diagram (per Acre) | Back to Input-Output | Next Graph

Year	1	2	3	4	5	6	7	8	9	10
Expenditures										
land costs and insurance	0	0	0	0	0	0	0	0	0	0
Administration cost	0	0	0	0	0	0	0	0	0	0
Planting and establishment cost	175.53	35.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Storage Cost	62.45	44.05	52.64	22.41	22.41	22.41	22.41	22.41	22.41	22.41
Stand maintenance cost	0	178.275	157.275	157.275	157.275	157.275	157.275	157.275	157.275	157.275
Harvest Cost	136.17	136.17	136.17	136.17	136.17	136.17	136.17	136.17	136.17	136.17
Transportation Cost	7.52	19.87	32.22	32.22	32.22	32.22	32.22	32.22	32.22	32.22
Total Expendituves	381.67	413.47	378.30	348.07	348.07	348.07	348.07	348.07	348.07	348.07
Revenues										
Acreage incentive Payments	0	0	0	0	0	0	0	0	0	0
Biomass	103.95	274.725	445.5	445.5	445.5	445.5	445.5	445.5	445.5	445.5
Total Revenue	103.95	274.725	445.5	445.5	445.5	445.5	445.5	445.5	445.5	445.5
Total Profit 1	-277.72	-138.74	67.20	97.43	97.43	97.43	97.43	97.43	97.43	97.43
Other costs										
Loan Payments	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Costs	381.67	413.47	378.30	348.07	348.07	348.07	348.07	348.07	348.07	348.07
Total Profit 2	-277.72	-138.74	67.20	97.43	97.43	97.43	97.43	97.43	97.43	97.43
Total 2 per ton of biomass produced	-198.36865	-37.498184	11.1994801	16.237678	16.237678	16.237678	16.237678	16.237678	16.237678	16.237678
Total Profit 2 discounted	-269.40	-130.59	59.66	84.00	81.15	78.39	75.73	73.16	70.67	68.27
Total Profit 2 accumulated	-269.40	-408.15	-340.95	-243.52	-146.10	-48.67	48.76	146.18	243.61	341.03
Total Profit 2 optimistic	-229.15	-69.92	149.58	176.78	176.78	176.78	176.78	176.78	176.78	176.78
Total Profit 2 optimistic, discounted	-222.47	-66.31	134.03	153.24	148.06	143.06	138.23	133.56	129.05	124.69
Total Profit 2 optimistic, accumlated	-229.15	-299.08	-149.50	27.28	204.07	380.85	557.63	734.42	911.20	1087.98
Total Profit 2 Pessimistic	-326.28	-207.56	-15.18	18.07	18.07	18.07	18.07	18.07	18.07	18.07
Total Profit 2 Pessimistic, discounted	-316.34	-194.87	-14.71	14.76	14.24	13.72	13.23	12.75	12.29	11.85
Total Profit 2 Pessimistic, Accumulated	-326.28	-533.84	-549.02	-530.96	-512.89	-494.82	-476.75	-458.68	-440.61	-422.54

Figure 3. The per acre section of the cash flow sheet.

Cost Distribution

The cost distribution worksheet is meant to show the user how the costs are spread out over the different activities associated with the production of switchgrass. It displays the land cost and insurance, administration cost, planting and establishment cost, storage cost, stand maintenance cost, harvest cost, and transportation cost per acre per year and in total per year. It then displays the percent of the total costs that each activity accounts for and shows this information in a pie chart.



Costs (per acre)	US$/acre	US$ total per year (avg.)	% of total
Planting and Establishment	175.53	877.64	4.70%
Stand Maintenance	159.61	7980.42	42.74%
Harvest	136.17	6808.59	36.46%
Land cost and insurance	0.00	0.00	0.00%
administration	0.00	0.00	0.00%
Transportation (average per year)	28.51225	1425.61	7.63%
Storage Cost	3.160069	1580.03	8.46%

Figure 4. The cost distribution sheet.

Yearly Cash flow

The yearly cash flow worksheet is intended to give the user a visual concept of the yearly positive or negative undiscounted revenues. Two separate bar chart diagrams display per acre yearly undiscounted revenues and the total yearly undiscounted revenues.

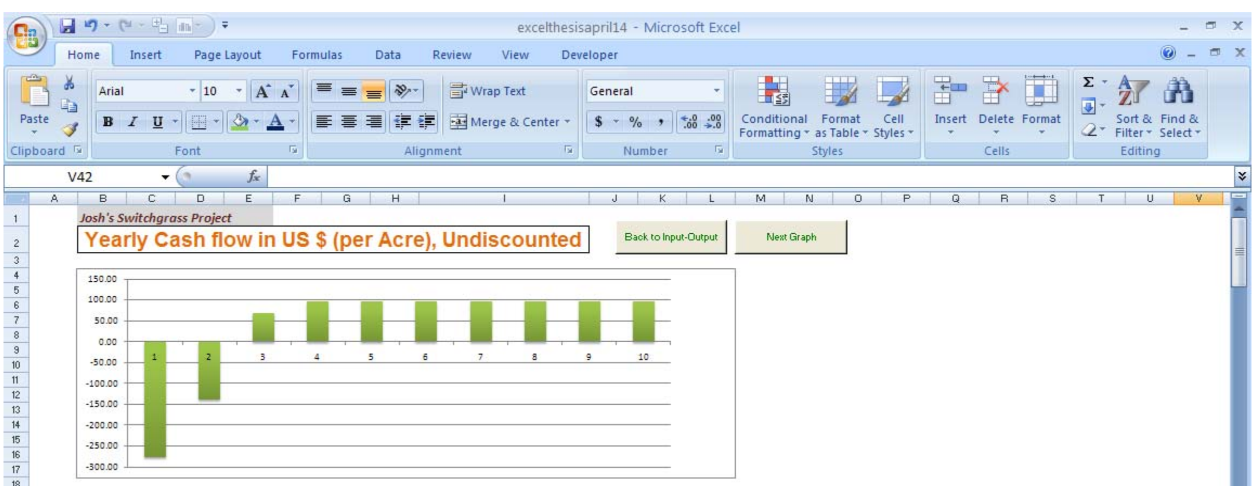


Figure 5. The per acre yearly cash flow diagram.

Accumulated Cash Flow

The accumulated cash flow worksheet is intended to give the user a visual idea of the accumulated cash flows for each successive year over the life of the project. Two separate line graphs show per acre accumulated cash flow and the total accumulated cash flow for each successive year over the life of the project.

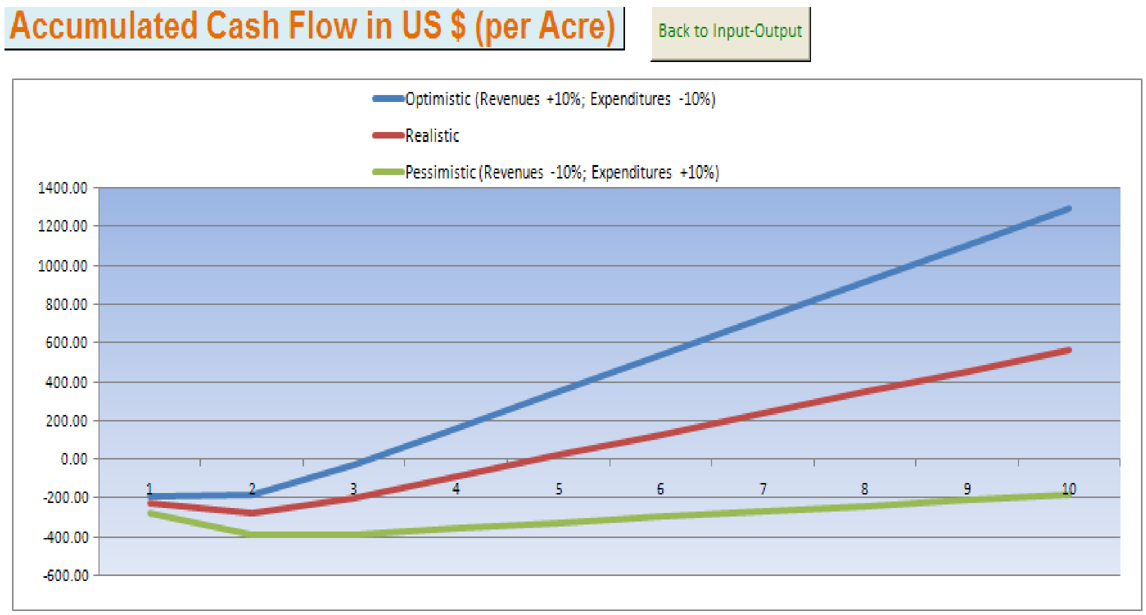


Figure 6. The accumulated per acre cash flow diagram.

NPV Sensitivity Analysis						
Price/dry ton	60	65	70	75	80	85
Mature yield						
5	-37723.11	-28586.33	-19440.65	-10294.92	-1149.19	7996.54
6	-22158.67	-11421.84	-685.02	10051.81	20788.64	31525.46
7	-6585.23	5742.69	18070.62	30398.54	42726.4	55054.39
8	8988.2	22907.23	36826.23	50745.27	64664.3	78593.32

Price where NPV is zero	70.32

Figure 7. NPV sensitivity analysis and NPV breakeven price.

Planting and Establishment Sheet

This sheet is designed to give the user the cost of planting and establishing his or her switchgrass stand during the first year of the project. There are six different sections of this worksheet including: general data, labor, travel costs, equipment, supplies, and a totals section.

The general data section includes acres to be planted, planting time in hours per acre, and total planting time in hours. The number of acres to be planted comes from the value given in the welcome sheet. Planting time is an estimate value that comes from the University of Tennessee Extension (2009) switchgrass budget. The user has the option to change this value if a more accurate figure is known. Total planting time is found by multiplying total acres to be planted by planting time in hours per acre.

The labor section contains the following values: number of crew on site, laborers per crew, laborer wage rate, hours at site per crew, indirect labor cost, the total labor cost, and the total labor cost per acre. The number of crews on site, laborers per crew, and laborer wage rate have values that are suggested by the University of Tennessee Extension (2009) switchgrass budget. These values may be adjusted by the user if more accurate figures are known. The number of hours spent at the site per crew is found by multiplying the planting time by the acres to be planted. The total labor cost is found by multiplying the number of crews at the site, total planting time, laborers per crew, laborer wage rate, and one plus the indirect labor cost percentage.

The travel cost section consists of the following subsections: number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, meal cost per day per person, and the total travel costs. The number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, and meal cost per person per day are adjustable values and can be altered by the user if more accurate figures are known. The travel cost section is borrowed from the State University of New York's poplar excel workbook.

Josh's Switchgrass Project

Planting and Establishment Submodel

General data				
Acres to be planted	acre	50		
Planting time	hrs/acre	0.68	0.68	**Equipment Delivery**
total planting time	hrs	34		

Labor				
No. of crews at site		1	1	
Labors/crew		1	1	
Laborer rate	$/hr	9.75	9.75	**Tractor**
hours at site/crew	Hrs	34		
Indirect labor costs	%	0	0	
Total	$	331.5		
Per acre		6.63		

Travel costs			
No. of vehicles		1	
Vehicle costs	$/mi	0.4	**No-till drill**
Distance	Mi	0	
total nights		0	
Hotel	$/night/person	0	
Meals	$/day/person	0	
Total	$	0	

Yellow cells: insert numbers, insert "0" if not applicable — **Sprayer 60" boom**

Grey cells: output from previous inputs

Figure 8. The general data, labor, and travel costs subsections of the planting and establishment sheet.

The equipment section of this worksheet is divided up into 5 subsections. These subsections are equipment delivery, tractor costs, not-till drill costs, sprayer costs, and mower costs. The recommended values in the adjustable cells in the section come from the University of Tennessee Extension (2009) switchgrass budget. The equipment delivery subsection contains value cells to represent transport cost per mile for the drill, tractor, sprayer, mower, distance to be transported, all of which are cells that allow adjustments by the user, and the total delivery costs. The total delivery cost is determined by summing all of the transport cost per mile and multiplying this figure by the distance both ways.

The tractor subsection of the equipment section contains the following value cells fixed costs per hour, variable costs per hour, hours per acre, fixed costs per hour, variable costs per hour, repair costs per acre, fuel costs per acre, and total tractor costs. Fixed costs per hour, variable costs per hour, hours per acre, repair costs per acre, and fuel costs per acre are all adjustable cells. The value for the fixed cost per acre is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre is found by multiplying the variable cost per hour by the hours per acre. Total tractor cost is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together.

The remaining 3 subsections in the equipment section; no-till drill cost, sprayer cost, mower costs, have the same costs categories: fixed cost per hour, variable costs per hour, hours per acre, fixed cost per acre, variable cost per acre, repair costs per acre, and total costs for each respective piece of equipment. Fixed costs per hour, variable costs per hour, hours per acre, and repair costs per acre for each respective piece of equipment are all adjustable cells. The value for the fixed cost per acre for each piece of equipment is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre for each piece of equipment is found by multiplying the variable cost per hour by the hours per acre. Total cost for each piece of equipment is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together. At the end of the equipment section the total cost of all the equipment is calculated. This is done by adding all of the individual equipment costs together. This total cost figure is then divided by the number of acres planted to give total equipment costs per acre.

Submodel

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	Equipment			
Equipment Delivery	transport for drill	$/mi	0	
	Transport for tractor	$/mi	0	
	Transport for sprayer	$/mi	0	
	Tranport for mower	$/mi	0	
	Distance	mi	0	
	Total delivery costs	$	0	
Tractor	Fixed cost per hour	$/hr	8.21	8.21
	Variable cost per hour	$/hr	29.04	29.04
	Hours per acre	hr/acre	0.54	0.54
	Fixed cost per acre	$/acre	4.43	
	Variable cost per acre	$/acre	15.68	
	Repair cost per acre	$/acre	4.38	4.38
	Fuel cost per acre	$/acre	11.31	11.31
	Total tractor costs	$	1005.75	
No-till drill	Fixed cost per hour	$/hr	11.49	11.49
	Variable cost per hour	$/hr	8.5	8.5
	Hours per acre	hr/acre	0.24	0.24
	Fixed cost per acre	$/acre	2.76	
	Variable cost per acre	$/acre	2.04	
	Repair cost per acre	$/acre	2	2
	Total drill costs	$	239.88	
Sprayer 60" boom	Fixed cost per hour	$/hr	5.78	5.78
	Variable cost per hour	$/hr	3.92	3.92
	Hours per acre	hr/acre	0.14	0.14
	Fixed cost per acre	$/acre	0.81	
	Variable cost per acre	$/acre	0.55	
	Repair cost per acre	$/acre	0.55	0.55
	Total sprayer costs	$	67.9	
Rotary mower 15'	Fixed cost per hour	$/hr	5.78	5.78
	Variable cost per hour	$/hr	3.92	3.92
	Hours per acre	hr/acre	0.1	0.1
	Fixed cost per acre	$/acre	0.58	
	Variable cost per acre	$/acre	0.39	
	Repair cost per acre	$/acre	1.14	1.14
	Total mower costs	$	48.50	
	Total equipment cost	$	1362.03	
	Total equipment cost per acre	$/acre	27.24	

Figure 9. The equipment costs subsection of the planting and establishment sheet.

The supplies section of the planting and establishment worksheet contains three subsections: seed costs, fertilizer costs, and burndown costs. All of the recommended values in this section come fromthe University of Tennessee Extension (2009) switchgrass budget. The seed costs subsection contains the price of seed per pound and the number of pounds of seed needed per acre. The fertilizer subsection contains the phosphorus pentoxide price per pound and pounds per acre as well as the potassium oxide price per pound and pounds per acre values. The burndown subsection contains the price per quart and the quarts per acre values for the fall burndown glycophosate.

	Supplies			
Seed	Seed Price	$/pound	8.25	
	Pounds Seed Per Acre	pounds/acre	6	6
Fertilizer	Fertilizer P205 Price	$/pound	0.8	0.8
	Fertilizer P205 Pounds per Acre	pounds/acre	40	40
	Fertilizer K20 Price	$/pound	0.75	0.75
	Fertilizer K20 Pounds per Acre	pounds/acre	80	80
Burndown and Herbici	Fall Burndown Glycophosate Price	$/qt.	7.87	7.87
	Fall Burndown Glycophosate Qt per Acre	Qt./acre	1	1
	Other supplies	$/acre		
	Establishment grant	$/acre	0	0
	Total	$/acre	7082.87	
	Total including grant	$/acre	7082.87	
	Total including grant per acre	$/acre	141.66	

TOTALS		
Labor	$	331.50
Travel	$	0.00
Equipment	$	1362.03
Supplies	$	7082.87
Total	$	8776.40
Total per acre	**$/acre**	175.53

Figure 10. The supplies costs and the total cost subsections of the planting and establishment sheet.

After the burndown cost section, the values for other supplies, the establishment grant, total supply cost, total supply cost including grant. The other supplies and establishment grant values are variable cells that can be changed by the user. The total supplies cost is found by multiplying the unit per acre amount of each item by the price per unit amount and then adding the other supplies cost. The total including grant is found by multiplying the establishment grant per acre figure by the number of acres to be planted then subtracting that amount from the total supplies cost. The total cost including grant per acre is found by dividing the total cost including grant by the number of acres to be planted.

The last section of the worksheet is the total costs section. In this section the total cost of the planting and establishment of the project is calculated. This is done by adding the total labor, total travel, total equipment, and total supplies costs together. The total cost per acre is found by dividing the overall total cost by the acres to be planted.

Stand Maintenance

The stand maintenance worksheet is designed to determine the cost of maintaining the stand of switchgrass for each year of the life of the stand after the first planting year. It contains the following values: project size, the pounds per acre of nitrogen, the price per pound of nitrogen, the pounds per acre of phosphorus pentoxide, the price per pound of phosphorus pentoxide, pounds per acre of potassium oxide, price per pound of potassium oxide, spring burndown quantity per acre, spring burndown price per acre, fall burndown quantity per acre, fall burndown price per acre, broadleaf herbicide quantity per acre, broadleaf price per quantity, grass herbicide quantity per acre, grass herbicide price per quantity, total stand maintenance cost, and total stand maintenance cost per acre. All of these values, with the exception of project size, total stand maintenance cost, and total stand maintenance cost per acre come from the University of Tennessee Extension switchgrass budget (2007).

The values for the pounds per acre of nitrogen, the price per pound of nitrogen, the pounds per acre of phosphorus pentoxide, the price per pound of phosphorus pentoxide, pounds per acre of potassium oxide, price per pound of potassium oxide, spring burndown quantity per acre, spring burndown price per acre, fall burndown quantity per acre, fall burndown price per acre, broadleaf herbicide quantity per acre, broadleaf price per quantity, grass herbicide quantity per acre, grass herbicide price per quantity are variable and can be changed by the user. The estimated figures used come from the University of Tennessee Extension (2007) switchgrass budget. The total stand maintenance cost per acre is found by multiplying the quantity per acre together with the price per quantity of each item in the stand maintenance section. The total stand maintenance cost is found by multiplying this number by the number of acres to be planted.

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Stand Maintenance Submodel

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General input data

Project Size		50	
Nitrogen	Pounds/acre	60	60
Nitrogen Price	$/pound	0.76	0.76
P_2O_5	Pounds/acre	40	40
P_2O_5 Price	$/pound	0.8	0.8
K_2O	Pounds/acre	80	80
K_2O Price	$/pound	0.75	0.75
Spring burndown	Quantity/acre	1.5	1.5
Spring burndown Price	$/quantity	7.87	7.87
Fall burndown	Quantity/acre	1	1
Fall burndown price	$/quantity	7.87	7.87
broadleaf herbicide	Quantity/acre	2	2
broadleaf herbicide price	$/quantity	2.5	2.5
grass herbicide	Quantity/acre	2	2
grass herbicide price	$/quantity	8	8
Total stand maintenance cost second year		8913.75	
Total stand maintenance cost second year per acre		178.275	
Total stand maintenance cost after second year		7863.75	
Total stand maintenance cost after second year per acre		157.275	
Total stand maintence cost second year per ton		48.18243	
Total stand maintence cost after second year per ton		26.2125	

Figure 11. The stand maintenance sheet.

Harvest Sheet

The harvest sheet is intended to determine the total cost associated with harvesting activities for each year of the life of the project. This sheet is broken down into five subsections that include: general input data, labor costs, travel costs, equipment costs, totals, and costs per ton per year. The general data section has cells for the acres to be harvested and the harvest speed in hours per acre. The number of acres to be harvested comes from the project acres cell in the welcome sheet. The harvest speed in hours per acre cell is an adjustable cell that allows the user to insert his or her estimation if a more accurate one is known. The suggested value for this cell comes from the University of Tennessee Extension (2007) switchgrass budget.

Josh's Switchgrass Project

Harvest Submodel

General Input Data			
Acres to be harvested	acres	50	
Harvest speed	hr./acre	1.48	1.48

Labor			
no. crews at site		1	1
Laborer/ crew		1	1
Foreman/crew		1	1
Laborer rate	$/hr	9.75	9.75
Foreman rate	$/hr	9.75	9.75
Hours at site/crew		74	
indirect labor costs	%	0	0
total	$	1443	
Total per acre	$/acre	28.86	

Travel Costs			
No of Vehicles		1	1
Vehicle costs	$/mi	0.4	0.4
Distance (one way)	mi	50	50
Total nights		0	0
Hotel costs	$/night/perso	0	0
Meal costs	$/night/perso	0	0
Total crew travel costs	$	20	

Yellow cells: insert numbers, insert "0" if not applicable
Grey cells: output from previous inputs

Figure 12. The general input, labor, and travel costs subsections for the harvest sheet.

The labor section of the harvest sheet contains nine value cells. These cells include: number of crew on site, labors per crew, foreman per crew, laborer wage rate, foreman wage rate, hours at site per crew, indirect labor cost, the total labor cost, and the total labor cost per acre. The number of crews on site, labors per crew, foreman per crew, laborer wage rate, and the foreman wage rate have values that are suggested by the University of Tennessee Extension (2007) switchgrass budget. These values may be adjusted by the user if more accurate figures are known. The number of hours spent at the site per crew is found by multiplying the planting time by the acres to be planted. The total labor cost is found by multiplying together the number of crews at the site, total planting time, laborers per crew, laborer wage rate, and one plus the indirect labor cost percentage.

The travel costs section of the worksheet contains seven value cells including: number of vehicles, vehicle cost, distance, total nights, hotel cost per person per night, meal cost per day per person, and the total travel costs. The number of vehicles, vehicle cost, distance, total nights,hotel cost per person per night, and meal cost per person per day all has adjustable values and can be altered by the user if more accurate figures are known.

The equipment section of this worksheet is divided into six subsections. These subsections are delivery cost, tractor costs, mower costs, rake costs, bailer costs, and loader costs. The recommended values in the adjustable cells in the section come from the University of Tennessee Extension (2007) switchgrass budget. The equipment delivery subsection contains value cells to represent transport cost per mile for the drill, tractor, sprayer, mower, distance to be transported; of which all are cells that allow adjustments by the user, and the total delivery costs. The total delivery cost is found by summing all of the transport cost per mile and multiplying this figure by the distance both ways.

The tractor subsection of the equipment section contains the following categories fixed costs per hour, variable costs per hour, hours per acre, fixed costs per acre, variable costs per acre, fuel costs per acre, and total tractor costs. Fixed costs per hour, variable costs per hour, hours per acre, and fuel costs per acre are all adjustable cells. The value for the fixed cost per acre is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre is found by multiplying the variable cost per hour by the hours per acre. Total tractor cost is found by multiplying the fixed cost and the variable cost per acre by the total acres to be planted and then adding them together.

The four remaining subsections in the equipment section; mower costs, rake costs, bailer cost, and loader costs, have the same costs categories: fixed cost per hour, variable costs per hour, hours per acre, fixed cost per acre, variable cost per acre, repair costs per acre, and total costs for each respective piece of equipment. Fixed costs per hour, variable costs per hour, hours per acre, and repair costs per acre for each piece of equipment are all adjustable cells. The value for the fixed cost per acre for each piece of equipment is found by multiplying the fixed cost per hour by the hours per acre. The value for the variable cost per acre for each piece of equipment is found by multiplying the variable cost per hour by the hours per acre. Total cost for each piece of equipment is found by multiplying the fixed cost and the variable cost by the total acres to be planted and then adding them together. At the end of the equipment section, the total cost of all the equipment is calculated. This is done by adding all of the individual equipment costs together. This total cost figure is then divided by the number of acres planted to give total equipment costs per acre.

Below the equipment section of the harvest worksheet is the total cost section. In this section, the total cost of the planting and establishment of the project is calculated. This is done by adding the total labor, total travel, and total equipment costs together. The total cost per acre is found by dividing the overall total cost by the acres to be planted.

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	Equipment			
Tractor	Fixed cost per hour	$/hr	8.21	8.21
	Variable cost per hour	$/hr	29.04	29.04
	Hours per acre	hr/acre	2.03	3.14
	Fixed cost per acre	$/acre	16.6663	
	Variable cost per acre	$/acre	58.9512	
	Fuel cost per acre	$/acre	42.56	42.56
	Total tractor costs	$	3780.875	
Mower	Fixed cost per hour	$/hr	3.3	3.3
	Variable cost per hour	$/hr	4.88	4.88
	Hours per acre	hr/acre	0.26	0.26
	Fixed cost per acre	$/acre	0.858	
	Variable cost per acre	$/acre	1.2688	
	Total mower costs	$	106.34	
Rake	Fixed cost per hour	$/hr	1.37	1.37
	Variable cost per hour	$/hr	0.72	0.72
	Hours per acre	hr/acre	0.17	0.29
	Fixed cost per acre	$/acre	0.2329	
	Variable cost per acre	$/acre	0.1224	
	Total rake costs	$	17.765	
Baler	Fixed cost per hour	$/hr	14.62	14.62
	Variable cost per hour	$/hr	13.8	13.8
	Hours per acre	hr/acre	0.75	0.75
	Fixed cost per acre	$/acre	10.965	
	Variable cost per acre	$/acre	10.35	
	Total baler costs	$	1065.75	
Loader	Fixed cost per hour	$/hr	7.27	7.27
	Variable cost per hour	$/hr	3	3
	Hours per acre	hr/acre	0.73	1.07
	Fixed cost per acre	$/acre	5.3071	
	Variable cost per acre	$/acre	2.19	
	Total loader costs	$	374.855	
	Total equipment costs	$	5345.585	
	Total equipment costs per acre	$/acre	106.9117	

TOTALS		
Labor	$	1443
Travel	$	20
Equipment	$	5345.585
Total	$	6808.585
Total per Acre	$/acre	136.1717

Figure 13. The equipment costs and total costs subsections of the harvest sheet.

The cost per ton of harvesting per year section is the last section of the harvest worksheet. It is intended to give the user an idea of how much of the cost per ton in each year is represented by the cost of harvesting the biomass. The value for each year is found by dividing the total harvest cost per year by the amount of biomass harvested in tons for each respective year.

Cost per ton by year	
Year	Harvest cost per ton
1	97.27
2	36.80
3	22.70
4	22.70
5	22.70
6	22.70
7	22.70
8	22.70
9	22.70
10	22.70

Figure 14. The harvest cost per ton by year.

Transportation Worksheet

The transportation worksheet is intended to show the user the transportation costs for each year over the life of the project. The worksheet has 13 sections that include: general data, labor costs, equipment costs, costs in year one, costs in year two, costs in year three, costs in year four, costs in year five, costs in year six, costs in year seven, costs in year eight, costs in year nine, and costs in year ten.

The general data section of the worksheet contains 9 value cells including: project size highway speed, field road speed, distance on highway (one way), distance on field road (one way), total driving time roundtrip, loading time, unloading time, and total time per trip. Highway speed, field road speed, distance on highway (one way), distance on field road (one way), loading time, and unloading time are all adjustable cells that the user can change. The suggested values for the adjustable cells in this section come from the eco-willow spreadsheet. Total driving time round trip is calculated by multiplying the distance on the highway and the distance on the field road by two, dividing each by the highway speed and the field road speed respectively, and then adding these two values together. Total time per trip is found by adding the loading time and the unloading time to the total driving time.

The labor costs section includes three value cells: driver wage per hour, indirect labor costs, and average loading and unloading costs. These cells may be adjusted by the user. The estimated value for the wage of the driver comes from Fulton (2009) and the value for the average loading and unloading cost comes from Wang (2009).

The equipment section includes four value cells: tractor-trailer costs per mile, fuel consumption in miles per gallon, fuel price, and maximum capacity in tons. Tractor-trailer costs per mile, fuel consumption in miles per gallon, and fuel price are cells that allow adjusting by the user. The estimated values for the tractor-trailer costs and fuel consumption come from Fulton (2009). The fuel price per gallon fluctuates daily and should be changed accordingly. The maximum capacity in tons is dependent on the type of bale used. If round bales are used, 36 bales with an average density of 0.4 tons/bale can be loaded onto each trailer. If rectangular bales are used, 24 bales with an average density of 1 ton/bale can be loaded on a trailer. These figures are taken from Wang (2009).

Each year of the project has a cost section to itself. Each year has the same value cells and the values are figured in the same manner, however, different values are used for different years. Each yearly cost section contains seven different value cells including: total trips, total time, labor, equipment, total per acre, and total per ton. The number of total trips is calculated by dividing the capacity of the tractor trailer by the amount of biomass mass harvested in each respective year. Total time is found by multiplying the total number of trips by the total time per trip. Total labor costs are found by adding average loading and unloading cost multiplied by total trips with the product of total time and the value found by adding driver wage with driver wage multiplied by indirect labor costs. The total equipment costs is found by multiplying together the product of distance on field road and distance on highway, the number two, and the product of the summation of tractor-trailer costs and the quotient of fuel consumption and fuel price and total trips. Total cost is the summation of total labor and total equipment costs. Total cost per ton is total cost divided by the tons of biomass harvested in each respective year.

Josh's Switchgrass Project

Transportation Submodel

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General Input Data

Project size	acres	50	
Highway Speed	mi/hr	50	50
Field road speed	mi/hr	20	20
Distance on highway (one way)	mi	25	25
Distance on field road (one way)	mi	1	1
Total driving time roundtrip	hrs	1.1	
Loading time	min	5	5
unloading time	min	15	15
Total time per trip	hrs	1.43333333	

Labor

Driver wage	$/hr	9.5	9.5
Indirect Labor costs	%	0%	0
Average Loading and unloading cost	$	16.2	16.2

Equipment

Tractor-trailer costs	$/mi	0.5	0.5
Fuel consumption	mi/g	7	7
Fuel price	$/g	3	3
Maximum capacity	tons	14.4	

Yellow cells: insert numbers, insert "0" if not applicable

Grey cells: output from previous inputs

Figure 15. The general data, labor costs, and equipment costs subsections of the transportation sheet.

Cost in year 1		
Total trips		4.81
Total time	hrs	6.90
Labor	$	143.49
Equipment	$	232.38
Total	$	375.87
Total per acre	$/acre	7.52
Total per ton	$/odt	5.42

Cost in year 2		
Total trips		12.72
Total time	hrs	18.23
Labor	$	379.23
Equipment	$	614.13
Total	$	993.36
Total per acre	$/acre	19.87
Total per ton	$/odt	5.42

Cost in year 3		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 4		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 5		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 6		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 7		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 8		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 9		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Cost in year 10		
Total trips		20.63
Total time	hrs	29.56
Labor	$	614.97
Equipment	$	995.89
Total	$	1610.86
Total per acre	$/acre	32.22
Total per ton	$/odt	5.42

Figure 16. The yearly transportation costs of the transportation worksheet.

Storage Worksheet

The storage worksheet is designed to cover the main issues associated with the storage of biomass. It gives the user the total loss of biomass, the total biomass that makes it to the plant gate, and the cost of storage per ton per year. The storage worksheet contains seven sections including: general data, bailing method, storage time, dry matter loss schedule by year in tons, total biomass making it to the plant, and cost of storage per ton per year.

The general data section has only one data cell, which is acres planted. The value of this cell comes from the welcome sheet. Likewise, the bailing method only has one data cell, the type of bailing method to be used. This cell may be adjusted by the user, but can only take on the value of rectangular bales or round bales. The storage time section contains three value cells, including storage time up to 200 days, percentage going directly to plant gate, and percentage being stored for up to 200 days. All three of these cells may be adjusted by the user by the user.

The storage method section gives the user the ability to choose which biomass storage method he or she will be using. There are 10 storage options that include: storing large round bales with a tarp and pallet, tarp and gravel, tarp on bare ground, pallet with no tarp, gravel with no tarp, bare ground no tarp, storing large rectangular bales using tarp and pallet, tarp and gravel, pallet and gravel, pallet with no tarp, and gravel with no tarp. With this spreadsheet, only one storage option may be chosen.

Josh's Switchgrass Project

Storage Submodel

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General data		
Acres planted	acres	50

Bailing method^		
	Choose one	Round bales

Storage time^		
Storage time up to 200 days	days	200
Percentage going directly to plant gate	%	0%
Percentage being stored for up to 200 days	%	100%

Storage method^	1 if yes, 0 if no	Dry matter loss after 200 days*
Large round bale		
Tarp and Pallet	1	1.0%
Tarp and gravel	0	8.5%
Tarp on bare ground	0	7.0%
Pallet no tarp	0	18.2%
Gravel no tarp	0	16.6%
Bare ground no tarp	0	12.8%
Large rectangular bale		
Tarp and pallet	0	13.7%
Tarp and gravel	0	28.0%
Pallet no tarp	0	48.0%
Gravel no tarp	0	57.1%

*Calculated from unpublished work by Burton English, James Larson and Don Tyler at Milan Research and Education Center.
^ Only one storage method and baling type may be used for storage loss calculation in this worksheet.

Figure 17. The general data, bailing method, storage time, and storage method subsections of the storage sheet.

The dry matter loss schedule by year in tons is intended to show the amount of dry matter the user can expect to lose due to weathering and decomposition. The amount of loss incurred is calculated by taking into consideration the percent of overall harvest that will be stored and the amount of time that it will be stored with the amount of dry matter loss to be expected with each storage type. The dry matter loss for each storage type comes from Wang (2009). The total amount of biomass making it to the plant is found by subtracting the amount of loss due to storage from the total amount harvested.

Dry matter loss schedule by year in tons										
Year	1	2	3	4	5	6	7	8	9	10
Storage method										
Large round bale										
Tarp and Pallet	0.7	1.85	3	3	3	3	3	3	3	3
Tarp and gravel	0	0	0	0	0	0	0	0	0	0
Tarp on bare ground	0	0	0	0	0	0	0	0	0	0
Pallet no tarp	0	0	0	0	0	0	0	0	0	0
Gravel no tarp	0	0	0	0	0	0	0	0	0	0
Bare ground no tarp	0	0	0	0	0	0	0	0	0	0
Large rectangular bale										
Tarp and pallet	0	0	0	0	0	0	0	0	0	0
Tarp and gravel	0	0	0	0	0	0	0	0	0	0
Pallet no tarp	0	0	0	0	0	0	0	0	0	0
Gravel no tarp	0	0	0	0	0	0	0	0	0	0

Figure 18. The dry matter loss schedule of the storage worksheet.

The total cost of storage by year section gives the total cost of storage for each year and the total cost of storage for each year per ton. The total cost for each year has to take into account the amount of storage materials that are still usable from the previous year in determining the amount of material that have to be bought in each current year. Tarps, pallets, and gravel all have different expected rates of replacement, so different storage types will have different material rollover percentages. The amount of materials that roll over from the previous year is subtracted from the amount that is needed in the current year to get the amount that has to be bought is the current year.

Storage costs per year										
Year	1	2	3	4	5	6	7	8	9	10
Storage method										
Large round bale										
Tarp and Pallet	3122.453	2202.434	2631.959	1120.5	1120.5	1120.5	1120.5	1120.5	1120.5	1120.5
Tarp and gravel	0	0	0	0	0	0	0	0	0	0
Tarp on bare ground	0	0	0	0	0	0	0	0	0	0
Pallet no tarp	0	0	0	0	0	0	0	0	0	0
Gravel no tarp	0	0	0	0	0	0	0	0	0	0
Bare ground no tarp	0	0	0	0	0	0	0	0	0	0
Large rectangular bale										
Tarp and pallet	0	0	0	0	0	0	0	0	0	0
Tarp and gravel	0	0	0	0	0	0	0	0	0	0
Pallet no tarp	0	0	0	0	0	0	0	0	0	0
Gravel no tarp	0	0	0	0	0	0	0	0	0	0

Figure 19. The storage costs per year in the storage sheet.

Biomass Harvested Worksheet

The biomass harvested worksheet is designed to tell the user how much biomass he or she can expect to get from the project in each year in total and per acre. The tons per acre value cells may be adjusted by the user. The values used are estimates that come from the UT switchgrass budget. With any crop, the weather and soil conditions of the region it is grown can have a great impact on how well it performs. Therefore, it is advisable that the user tries to find the estimated switchgrass yield for his or her area.

Josh's Switchgrass Project

Biomass harvested Submodel

Back to Input-Output

Acres planted 50 Mature stand yield in tons/acre 6

Estimated harvest in tons per acre

Year	1	2	3	4	5	6	7	8	9	10
Tons/acre	1.4	3.7	6	6	6	6	6	6	6	6

Estimated harvest in tons per year

Year	1	2	3	4	5	6	7	8	9	10
Tons/acre	70	185	300	300	300	300	300	300	300	300

Figure 20. The biomass harvested sheet.

Conclusions

This paper explained how an adjustable excel spreadsheet decision tool for potential switchgrass producers was made. It shows where values for costs incurred at each level of production are derived from as well as the costs for storage and transportation of the final baled switchgrass. A major hurdle to overcome with the production of switchgrass, as with any innovation, is the lack of knowledge that potential adopters have about it and consequentially the sense of risk that may accompany its implementation. This paper and the associated decision tool have aimed at and hopefully succeeded in reducing this lack of knowledge.

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Part 4: Conclusions

Conclusions

This study analyzed the influences that various socioeconomic and farm characteristics have on producers' interest in growing and the extent to which they would be willing to produce switchgrass given different plant gate prices. The results of this study have several possible implications for switchgrass production and adoption expansion efforts in the southeastern United States. Based on the results, individuals and organizations that want to promote interest in adopting switchgrass may want to emphasize switchgrass' positive attributes, such as its potential for lowering input requirements, its ability to diversify a producer's crop mix, and the possibility of it contributing to the nation's energy security and environment. Also, farmers that have erosion problems on their land showed higher interest in switchgrass production, which means that switchgrass' ability to reduce erosion compared to more traditional crops could be emphasized as well. Concerns that affect producers' interest in growing switchgrass that likely need to be addressed through educational programs include management techniques to deal with possible conflicts between the planting and harvesting of switchgrass and other crops, contract arrangements that enable planting of switchgrass on land that is leased, and efficient use of financial and equipment resources needed to produce switchgrass.

From the results, it can be concluded that older producers would be less interested in switchgrass production, as they may not continue farming long enough to see the full benefits of a switchgrass stand. Those producers that operate a beef cattle operation are likely to be less interested, as well. This may be due to the reluctance of these producers to convert acres of pasture to switchgrass production and seems to indicate that areas with a high percentage of beef cattle farmers may not be an ideal switchgrass production area. Contrarily, producers that own hay equipment or have used custom hay harvest service may be more likely to be interested in growing switchgrass. Hence, switchgrass may be first adopted by producers who already have equipment that may be helpful in growing switchgrass.

The results of this study indicate that the share of acres that would be converted to switchgrass will be less on a larger farm. Also, while older farmers may be less willing to adopt switchgrass, those that do may be willing to devote more acreage that a younger farmer. This indicates that areas with smaller farms and younger farmers, on average, may show more acres being converted to switchgrass, ceteris paribus. Those producers who are reluctant to adopt a new crop before they see it work for others reasonably may show less interest in producing switchgrass and if they are willing to adopt, will likely convert a smaller share of acreage to switchgrass. Producers with a higher percentage of acreage devoted to CRP land may show a likelihood of devoting a smaller share of acres to switchgrass, which indicates that areas with producers that have a higher portion of their land devoted to CRP may devote a smaller portion of acres to switchgrass. This result suggests that CRP rules may need to be modified to encourage switchgrass production in a sustainable way on CRP lands. The results show that producers are sensitive to price with respect to both adopting switchgrass and the share of acres they would be willing to convert, indicating that a higher price offered at the plant gate should mean that a bio-refinery will receive more biomass.

This study has given new information about switchgrass production from the producer's prospective in the southeastern U. S. However, there is still a substantial lack of knowledge in related areas, such as contract preferences or harvesting and storage arrangements, that future studies can build upon.

This paper also explained how an adjustable excel spreadsheet decision tool for potential switchgrass producers was put together. It showed where values for costs incurred at each level of production are derived from as well as the costs for storage and transportation of the final baled switchgrass. It addresses a major hurdle with the production of switchgrass, as with any innovation, the one of lack of knowledge that potential adopters have about it and the risk that accompanies this perceived risk. This paper and the associated decision tool aimed at and hopefully succeeded in reducing this lack of knowledge.

Vita

Donald Joshua Qualls was born in Dyersburg, Tennessee on February 19, 1987. He graduated from Obion County Central High School in 2005. In the fall of the same year, he enrolled in the University of Tennessee at Martin where he graduated with a Bachelors of Science in Agriculture Business in December of 2008. In August of 2009 he entered the Master of Science program in Agricultural Economics at the University of Tennessee at Knoxville. He completed the Master of Science degree in May of 2011.