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Intent to Continue Growing Switchgrass as a Dedicated Energy Crop: A Case Study of Switchgrass Producers in East Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by Jessica Elise Fox entitled "Intent to Continue Growing Switchgrass as a Dedicated Energy Crop: A Case Study of Switchgrass Producers in East Tennessee." 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.

Margarita M. Velandia, Roland K. Roberts, Major Professor

We have read this thesis and recommend its acceptance:

Burton C. English, Dayton M. Lambert

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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INTENT TO CONTINUE GROWING SWITCHGRASS AS A DEDICATED ENERGY CROP:

A CASE STUDY OF SWITCHGRASS PRODUCERS IN EAST TENNESSEE

A Thesis
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Abstract

Efforts to reduce the United States' dependence on foreign petroleum encourage the production of fuels from bioenergy crops. Recent energy mandates have therefore "opened doors" for alternative feedstock sources for ethanol production. Switchgrass is a candidate feedstock. Under the University of Tennessee's Biofuels Initiative, the University of Tennessee, partnering with DuPont-Danisco Cellulosic Ethanol LLC, contracted for the production of switchgrass with local farmers to guarantee biomass feedstock supply for an ethanol conversion research facility. This study used methods borrowed from the social psychology literature in combination with economic theory to analyze factors influencing switchgrass farmers' intentions to continue growing switchgrass after contracts with the granting agent expired. Understanding what motivates producers to make long term commitments to switchgrass production as an energy crop may be important information for private investors who will rely on a fixed supply of switchgrass.

A probit model was used to determine the factors affecting producers' intentions to continue producing switchgrass after their contract expires. Results suggest that community perceptions about the production of switchgrass as a dedicated energy crop may have an important impact on farmers' intentions to make a long-term commitment to produce switchgrass. Therefore, educating and involving community and extension personnel may have a positive impact on farmers' decisions to make long-term commitments to grow switchgrass as a dedicated energy crop.

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Chapter 1: Introduction

Problem Identification and Explanation

Efforts to reduce the United States' dependence on foreign petroleum encouraged the production of fuels from bioenergy crops. The 2007 Energy Independence and Security Act (EISA) mandated that 36 billion gallons per year of ethanol be produced in the United States by 2022, with 21 billion gallons per year from feedstocks other than corn (U.S. Congress, 2007). Perlack et al. (2005) and English et al. (2006) estimated that more than a billion tons of cellulosic feedstock could be produced annually for ethanol production in the U.S. English et al. (2006) indicated this can be achieved while anticipating an affordable abundant supply of food, feed, and fiber. With the aggressive goal set under the 2007 EISA, cellulosic materials from "dedicated energy crops" such as switchgrass [*Panicum virgatum* (L.)], corn stover, wheat straw, poplar, and wood waste products will be needed to meet demand targets (De La Torre Ugarte et al., 2007a; De La Torre Ugarte, English, and Jensen, 2007b).

Setting the goal, established under the 2007 EISA, implies that a cellulosic ethanol industry could emerge by 2020. This task will require a high level of capital investment to develop infrastructure and market channels, as well as secure feedstock supply channels (Epplin et al. 2007; Kenkel and Holcomb, 2009; Larson, 2008). Unlike the grain-based ethanol industry, a cellulosic-based ethanol industry will require considerable investment in the development of feedstock, storage and handling infrastructure; e.g., retrofitting pipelines, and maintenance barges to transport ethanol on navigable waterways (Epplin et al., 2007; Kenkel and Holcomb, 2009; Larson, 2008).

Switchgrass is considered to be an attractive biomass source of energy given its capacity to be grown on marginal lands with relatively few inputs (Kenkel and Holcomb, 2009).

Switchgrass is a perennial crop, and can be planted, managed, and harvested with conventional forage equipment already in use on crop and livestock farms. Switchgrass is native to the Eastern United States as well as the Great Plains and adapts well to different climatic and soil conditions (Jensen et al., 2006). The production of switchgrass as a dedicated energy crop may also have environmental benefits including reduced reliance on fossil fuels and a reduction of atmospheric CO_2 accumulation (Bransby, 1998). Switchgrass production could also stabilize or increase farm income given an increasing demand for alternative feedstock biomass (De la Torre Ugarte et al., 2007a).

Switchgrass requires three years to reach its maximum yield potential; therefore, the crop needs an upfront investment to establish stands. Farmers' abilities to respond to a potential market for switchgrass as a dedicated energy crop will depend on their capacity to handle on-farm economic, structural, and resource constraints (Larson, 2008). Given that there are limited or no alternative markets for this crop at present, future profitability of the crop may be unclear to producers (Kenkel and Holcomb, 2009; Larson, 2008). Additionally, harvesting and storage of switchgrass still presents a major challenge for farmers because the crop is relatively unwieldy (Epplin et al., 2007; Larson, 2008).

The development of a cellulosic industry in Tennessee and elsewhere will require relatively large capital outlays from private investors, and guaranteed feedstock supply from farmers. Producers will not continue investing resources in producing switchgrass as a dedicated energy crop unless local markets emerge in the short-to-medium term. Private investment is also unlikely if supply of biomass feedstock is inconsistent (Kenkel and Holcomb, 2009). Learning about the factors that contribute to intentions of producers currently under contract to continue growing switchgrass after their current contracts expire is important to anticipate farmers' long-

term commitments to supply feedstock until markets fully develop. Developing an understanding of farmers' behaviors towards switchgrass production implies not only the development of an understanding of the economic motives behind their intentions to continue growing switchgrass as a dedicated energy crop (i.e., potential profits of switchgrass as a dedicated energy crop), but also an understanding of individual beliefs and social values behind the intentions to continue growing switchgrass as a dedicated energy crop. An evaluation of the effects of individual and social factors on the intentions to continue growing switchgrass provides a broader perspective of the motives behind farmers' long-term commitment to grow switchgrass as a dedicated energy crop given there are no markets for this crop at present.

To initiate the development of a biomass energy industry, the state of Tennessee initiated the Biofuel Initiative hereafter called the UTBI. The UTBI uses a business model where private investors contract directly with farmers over a three-year production period to guarantee feedstock supply for a cellulosic ethanol conversion facility. UTBI was established by state legislation in 2007. Under this initiative, the University of Tennessee through Genera Energy LLC teamed with an industrial partner, DuPont Danisco Cellulosic Ethanol LLC, to construct and operate a 250,000 gallon per year cellulosic ethanol conversion research facility located in Vonore, Tennessee (Larson, 2008; Larson and English, 2009). The research facility was designed to initially use corn cobs, and then adjust production to use switchgrass as the primary feedstock (Larson and English, 2009).

Objectives

This thesis explores the factors affecting producers' attitudes and intentions to make a long-term commitment to produce switchgrass as a dedicated energy crop in the context of the UTBI. The specific objective of this study is to explore the effects of producers' attitudes

towards switchgrass production, social values, and perceptions of ability in terms of power and control over a new and potentially risky endeavor on switchgrass farmers' willingness to participate in the UTBI project, and their willingness to continue producing switchgrass after current contracts expire.

Understanding how producers' intentions, motivations, and beliefs affect their decisions to make long-term commitments to produce switchgrass as an energy crop will be important information for private investors and policy makers. This information will also aid in the design of strategies to encourage farmers to commit to the long term production of switchgrass as a dedicated energy crop.

The University of Tennessee Biofuels Initiative

To guarantee switchgrass supply for the ethanol conversion facility, UTBI entered into contracts in 2008 and 2009 with local farmers to produce about 2,700 acres of switchgrass. To receive a contract for the 2008 crop year, producers had to apply with the UTBI. The application consisted of several questions that allowed the UTBI to judge farmer ability to successfully grow switchgrass as a dedicated energy crop. The 2008 application collected information on: distance from the farming operation to the cellulosic ethanol conversion facility, the number of acres a producer was willing to commit to the program, the percentage of land owned relative to the percentage of land rented, inside and outside storage capacity, access to hay equipment, and farming experience. The application for the 2009 crop year asked for additional information: had the farmer been dishonorably discharged from the military, had the farmer been convicted of a crime, and did the farmer have access to equipment including sprayers and tractors.

The 40 farmers who signed contracts in 2008/2009 were guaranteed $450/acre payments for switchgrass for three years. Guaranteed per acre payments were used to minimize producer's

share of risk associated with production and also to create incentives for participation. In 2010, UTBI contracted for an additional 1,930 acres. This acreage was split between some of the original 40 farmers who signed contracts in 2008/2009, and 20 new farmers, for a total of 60 farmers currently contracting switchgrass production with UTBI. Farmers who contracted for switchgrass production in 2010 were guaranteed per–acre payments for the first year of the contract, followed by a combination of per-acre and per-ton payments for the remaining two years of the contract. UTBI sees the potential to expand production to 25,000 acres or more in the future, depending on market conditions and the success of the pilot plant. Producers are required to keep extensive records and follow production practices set up by UTBI to be eligible for payments under contract terms (Larson and English, 2009). Switchgrass seed was provided to producers along with guidance in planting, managing, and harvesting the crop from the University of Tennessee Extension.

This study focuses on characterizing the experience of the producers who signed contracts between 2008 and 2009 by the original 40 farmers with the University of Tennessee Biofuels Initiative (UTBI). Additionally, this study will investigate the factors affecting the intentions of these farmers to continue growing switchgrass as a dedicated energy crop after their contract with UTBI expires.

Chapter 2: Literature Review

Literature Review

Previous studies have focused on farmers' intentions to adopt switchgrass as a dedicated energy crop, the number of acres that could be converted to switchgrass production, and the motivations, reasons, and perceived barriers influencing adoption of this energy feedstock (Bransby, 1998; Hipple and Duffy, 2002; Jensen et al., 2006). Existing research suggests that a better understanding of the real potential of switchgrass for energy production requires more accurate information about bioenergy feedstock markets. Accurate estimation of potential switchgrass supply would require a more thorough comprehension of the factors motivating or impeding producers' decisions to include switchgrass or other biomass energy sources into their production portfolios. Hipple and Duffy (2002) used adoption-diffusion theory (Rogers, 1995) to understand farmers' motivations, constraints, and perceived consequences of adopting switchgrass as a biomass source for energy production. Using a survey instrument, they recorded the opinions of an agricultural community in Iowa, including switchgrass and non-switchgrass farmers, Extension personnel, and agribusiness representatives. The authors identified the motivations, incentives, consequences, and crop production attributes influencing the adoption of switchgrass as a dedicated energy crop. They found that expected profitability, concordance with family and community values and beliefs regarding switchgrass as an energy crop, erosion control benefits of the crop, and perceived improvements in water quality were positively associated with adoption. On the other hand, mistrust of government agencies and general uncertainty about the profitability of the crop discouraged adoption.

Jensen et al. (2006) studied the factors associated with the willingness of Tennessee farmers to produce switchgrass as a dedicated energy crop, as well as the number of farm acres

they were willing to allocate towards production. A large proportion of producers were unsure whether they would allocate acres to switchgrass because they were unfamiliar with the use of the crop as a bioenergy feedstock. Farmers expressing interest in growing the crop were willing to convert about 67 acres (on average) to switchgrass. Net farm income per acre, acres farmed, the number of crops grown, producer's age, and membership in grower/commodity organization were negatively correlated with the number of acres producers were willing to convert to switchgrass production. On the other hand, the percentage of income from farming, ownership of hay equipment, education level, and location in a county with a coal-fired plant were positively associated with switchgrass acreage supply.

Bransby (1998) studied producer willingness to grow switchgrass as a dedicated energy crop among Alabama farmers between 1994 and 1997. Producer expectations about minimum profits needed to justify production of switchgrass as a dedicated energy crop increased by about $10/acre/year (on average) between 1994 and 1997. A large percentage of managers included in this study (83%) expressed interest in signing long-term contracts to produce switchgrass as an energy crop.

Theory of Planned Behavior (TPB)

Previous studies have looked at farmers as consumers of agricultural technologies and alternative crop opportunities. From this perspective farmers have subjective preferences and perceptions about the options available to them. Economic studies have looked at adoption decisions based on different farm and farmer characteristics (Rahm and Huffman, 1984; McNamara et al., 1991; Roberts et al., 2004). Usually decision making studies in the context of agriculture do not use a specific framework to model the development of the farmer's attitudes toward adoption decisions. They therefore fail to appreciate the full complexity of attitude

development and its association with adoption behavior (Hattam, 2006). Practitioners of the social psychology approach have identified weaknesses in approaches that exclude attitudes toward the surrounding environment and the actual effort necessary to carry out the intended action (e.g., Edwards-Jones et al., 1998). They recognize the social psychology approach as being complementary to the random utility approach commonly used by economists (Edwards-Jones et al., 1998; Hattam, 2006).

Previous studies have used an alternative approach borrowed from social psychology science, the Theory of Plan Behavior (TPB), to understand and describe producers' behavior in terms of agricultural decision making (Hattam 2006; Beedell and Rehman 1999; Lynne et al.1995). The TPB approach provides a research framework to understand individuals' behavior through their intentions (Ajzen, 1988, p.113 – 132). Attitudes, subjective norms, and perceived behavioral controls are considered to be the primary determinants of behavioral intentions according to TPB. Additionally, factors such as demographic characteristics may play a role in the formation of intentions, and therefore the performance of a behavior (Hattam, 2006). Intentions are considered to be accurate predictors of actions. However, the focus of the TPB approach is not the predictive power of intentions themselves, but the understanding of human behavior through the factors determining behavioral intentions.

Using TPB, Hattam (2006) was able to identify factors that could not be identified through expected utility modeling of adoption decisions. She found that large-scale conversion to another production practice (organic agriculture) was unlikely in the short term. Hattam (2006) also found that having positive attitudes towards the adoption of a practice is not sufficient to induce adoption. Perceived inability to successfully adopt the alternative practice and social

pressures from important reference groups were major factors contributing to the inability of farmers to convert positive attitudes toward a practice into adoption behavior.

Beedell and Rehman (1999) illustrate the usefulness of the TPB by exploring producers' conservation behaviors using this approach. Specifically, they analyze how and why farmers manage hedges in Bedfordshire County, United Kingdom using the TPB approach. They found that farmers who are more conscious about the conservation of the environment place mere value on hedge management. Additionally, these farmers were more likely to be influenced by the social pressure of other groups in the society about farmers' actions toward environmental conservation.

Lynne et al. (1995) used the TPB approach to analyze strawberry producers' attitudes towards the adoption of water conservation technologies in Florida. Attitudes towards these technologies, what "others" think about the importance of water conservation technologies, as well as farmers' perceptions of the control they have over factors associated with the adoption of these technologies were found to be important in trying to understand farmers' behavior towards the adoption of water conservation technologies.

In the context of the current study, the TPB approach is used in combination with the random utility model approach, traditionally used in economic theory as a way to maximize behavior, to evaluate factors affecting the formation of intentions when farmers evaluate the opportunity to continue the production of switchgrass after contracts with the granting agency expire. The analysis does not portend to predict switchgrass producers' intentions to grow switchgrass. Instead, the goal of this research is to understand the basis of the intentions guiding farmers' decisions to continuing to grow switchgrass following expiration of a three-year contractual agreement.

Chapter 3: Conceptual Framework

Factors Affecting Decisions to Continue Producing Switchgrass: The Random Utility Model

Switchgrass producers are assumed to be rational decision makers who maximize the discounted expected benefits from farming. Producers' uncertainty about future income from switchgrass production as a dedicated energy crop, given that a market has not yet been developed, may induce them to stop growing switchgrass after the contract with the granting agency expires. Switchgrass producer i faces the decision to continue growing switchgrass after his/her contract expires. The utility producer i expects to receive if he/she continues growing switchgrass can be represented by a random utility model such that:

(1) $$U_{is} = V_{is} + \varepsilon_{is}$$

where V_{is} is the deterministic component of the utility from continuing the production of switchgrass as a dedicated energy crop and ε_{is} is the random component. The deterministic component V_{is} may depend on attributes associated with switchgrass production. The utility received from switchgrass production may also vary by age, and farm size. The deterministic part of the utility in the random utility model's framework is usually assumed to be linear in parameter, and can be represented as:

(2) $$V_{is} = x'_{is}\beta_s,$$

where x_{is} is a vector of attributes associated with switchgrass production that are unique for each farmer given farm characteristics, farmer management skills (e.g. expected profits from switchgrass production, effort require to grow switchgrass), and farm/farmer characteristics of switchgrass producer i and β_s is the parameter associated with the deterministic component of the utility function.

The potential for a farmer to continue producing switchgrass as a dedicated energy crop after his/her contract with the granting agency expires can be evaluated by comparing the utility that farmer i obtains from continuing switchgrass production (U_{is}) with the utility he/she obtains from not continuing switchgrass production (U_{ins}). The difference between the latent variables U_{is} and U_{ins} can be represented as:

(3) $$\mu_{is} = U_{is} - U_{ins},$$

where μ_{is} can be positive, negative or equal to zero. Substituting, equations (1) and (2) into (3), and expanding U_{ins}, (3) can be re-written as:

(4) $$\mu_{is} = x'_{is}\beta_s - x'_{ins}\beta_{ns} + (\varepsilon_{is} - \varepsilon_{ins}),$$

where x'_{ins} is a vector of attributes associated with the alternative of discontinuing switchgrass production that are unique for each farmer given farm characteristics, farmer management skills, and farm/farmer characteristics of switchgrass producer *i*; β_{ns} are vectors of parameters associated with the deterministic component of the utility from discontinuing switchgrass production as a dedicated energy crop, and ε_{ins} is the random component of the utility from discontinuing switchgrass production. A farmer will have intentions to continue growing switchgrass after his/her contract expires if $\mu_{is} > 0$.

Theory of Planned Behavior and the Random Utility Model

The Theory of Planned Behavior (TPB) is incorporated into the random utility model described above. It is assumed that the utility a farmer perceives from continuing growing switchgrass is not only affected by demographic characteristics, and the attributes associated with switchgrass production, as presented in equation (2), but also by the attitudes towards the production of switchgrass (i.e. attitudes), what others in the community think about the

production of switchgrass as a dedicated energy crop (i.e. subjective norms), and the control the farmer perceived having over the problems they may have faced when growing switchgrass as a dedicated energy crop (i.e. perceived behavioral control). These variables may also affect the perceived utility from not growing switchgrass as a dedicated energy crop. Since farmers form their intentions to continue growing switchgrass after their contract expires based on the differences between the utility of producing and not producing switchgrass, as describe in equation (4), and utility is a function of attitudes, subjective norms, and perceived behavioral control; therefore, intentions are also determined by attitudes, normative beliefs, and perceived behavioral control, as hypothesized by the TPB approach.

According to the TPB approach, intentions to follow an action (e.g. technology adoption, new crop adoption, and long-term commitment to switchgrass production) are determined by attitudes towards a behavior, perceived social acceptance/rejection towards a behavior (i.e. subjective norms), and perceived control over the ability to perform a behavior (i.e. perceived behavioral control). Attitudes towards a behavior are described as an individual's evaluation (either positive or negative) towards the performance of that particular behavior. On the other hand, proscribed subjective norms take into consideration social acceptance or rejection of a particular behavior as a potential factor affecting an individual's intention to perform a behavior (e.g., important members of the community believe that growing switchgrass is beneficial or harmful for the community in general and for the individual in particular). Finally, perceived behavioral control is the individual's perception of how easy or difficult the performance of a behavior is; for example, a farmer's confidence in his/her ability to continue growing switchgrass as a dedicated energy crop (Ajzen, 1988, p. 132).

According to the TPB, attitudes are formed by two components: 1) beliefs about the likely outcomes of the action (e.g., behavioral beliefs), and 2) the evaluation of the outcome or perceived probability that the outcome will actually happen. Therefore, attitudes ($Attitude$) can be estimated by the sum of behavioral beliefs (b_{ik}) weighted by the evaluation of those behavioral beliefs (e_{ik}) such that $Attitude \propto \sum_{k=1}^{n_k} b_{ik}\, e_{ik}$. This expression implies that if an individual believes that a behavior results in several positive outcomes, the attitude that an individual has towards that behavior may be most likely positive. For example, if a farmer believes a long-term commitment to switchgrass production as a dedicated energy crop will increase and stabilize farm income, allocate equipment and time resources more efficiently during the off season, and diversify farm outputs, they may be more likely to think that growing switchgrass is beneficial for them (Ajzen, 1988, p.120).

Under the TPB framework, subjective norms are formed by two components: 1) beliefs about other's approval of disapproval of a behavior (normative beliefs) and 2) motivations to comply with others' opinions about the behavior. Subjective norms ($SubjectiveNorm$) can be estimated by the sum of normative beliefs (b_{ij}) weighted by the motivation to comply with those beliefs (m_{ij}) such that $SubjectiveNorm \propto \sum_{j=1}^{n_j} b_{ij}\, m_{ij}$. This expression implies that if individuals who may affect farmer's production decisions (e.g., family, Extension personnel, and other farmers) believe that a long-term commitment to produce switchgrass as a dedicated energy crop is "good", farmers may be more likely to have positive intentions to continue growing switchgrass as a dedicated energy crop (Ajzen, 1988, p.121).

Finally, TPB describes perceived behavioral controls as a factor formed by two components: 1) beliefs about the presence of factors that may facilitate or obstruct performance of the action (e.g. control beliefs) and 2) the perceived power of control over these factors.

Perceived Behavioral Control ($PercievedBehavioralControl$) can be estimated by the sum of control beliefs (p_{il}) weighted by the control the individual perceived having over those beliefs (c_{il}) such that $PercievedBehavioralControl \propto \sum_{l=1}^{n_l} p_{il}\, c_{il}$. This expression summarizes perceptions about the power of control over those factors farmers think may prevent or permit the continuation of switchgrass production as a dedicated energy crop (e.g., weed control, equipment breakdowns associated with switchgrass production) (Ajzen, 1988, p.132).

Attitudes, subjective norms, and perceived behavioral control are considered to be the main determinants of behavioral intentions. Additionally, factors such as demographic characteristic may have an additional role in the formation of intentions, and therefore the performance of a behavior (Hattam, 2006).

The deterministic component of the perceived utility from continuing switchgrass production presented above is expanded to incorporate the variables forming behavioral intentions under the TPB approach. Equation (2) is expanded to include the variables under the TPB approach:

$$V_{is} = x'_{is}\beta_s + \left(\sum_{k=1}^{n_k} b_{ik} e_{ik}\right)\ \delta_s + \left(\sum_{j=1}^{n_j} n_{ij} m_{ij}\right)\ \lambda_s + \left(\sum_{l=1}^{n_l} p_{il} c_{il}\right)\ \eta_s, \tag{5}$$

where b_{ik} represents behavioral beliefs (e.g. switchgrass is going to result in long-run income improvement); e_{ik} represents evaluation of behavioral beliefs (from extremely unlikely to extremely likely); n_{ij} represents normative beliefs (e.g., opinions of family about switchgrass production as a dedicated energy crop); m_{ij} represents motivation to comply with social rules and perceptions; p_{il} represents control beliefs (e.g., perception of managerial capacity for growing switchgrass); c_{il} represents the strength of each control belief; δ_s, λ_s , and η_s, represent empirical derive weights. The deterministic component of the perceived utility from

discontinuing switchgrass production is also affected by attitudes, subjective norms, and perceived behavioral control associated with switchgrass production:

$$(6) \qquad V_{ins} = x'_{ins}\beta_{ns} + \left(\sum_{k=1}^{n_k} b_{ik}e_{ik}\right)\ \delta_{ns} + \left(\sum_{j=1}^{n_j} n_{ij}m_{ij}\right)\ \lambda_{ns} + \left(\sum_{l=1}^{n_l} p_{il}c_{il}\right)\eta_{ns},$$

where δ_{ns}, λ_{ns} , and η_{sn}, represent empirically derived weights. The random utility model presented above is also expanded to incorporate the variables forming behavioral intentions under the TPB approach. Equation (4) can be re-written as:

$$(7)\ \mu_{is} = x'_{is}\beta_s - x'_{ins}\beta_{ns} + \left(\sum_{k=1}^{n_k} b_{ik}e_{ik}\right)\delta_s - \delta_{ns} + \left(\sum_{j=1}^{n_j} n_{ij}m_{ij}\right)\lambda_s - \lambda_{ns} + \left(\sum_{l=1}^{n_l} p_{il}c_{il}\right)\eta_s - \eta_{ns} + \varepsilon_{is} - \varepsilon_{ins}.$$

Note that μ_{is} in equation (7) is an unobserved latent variable, but farmers' intentions to continue growing switchgrass as a dedicated energy crop after their contract with the granting agency expires (BI) can be evaluated such that:

$$(8) \qquad BI = \begin{cases} 1 & \text{if } \mu_{is} > 0 \mid y_i > 0 \\ 0 & \text{if } \mu_{is} \le 0 \end{cases},$$

where $BI = 1$ if a producer has intentions to continue growing switchgrass, and $BI = 0$ otherwise. Intentions to continue growing switchgrass after the contract expires are observed only for farmers who already have a contract to produce switchgrass with the granting agency ($y_i > 0$; detailed definition in next sections).

Sample Selection Bias

Intentions to *continue* growing switchgrass as a dedicated energy crop after contracts expire with the granting agency can only be expressed by individuals who already had a contract for switchgrass production with the University of Tennessee Biofuels Initiative. Although farmers decided whether or not to apply for a contract to produce switchgrass, they did not self-

select when obtaining a contract. Under the UTBI initiative farmers were selected by the granting agency based on the selection criteria (e.g. distance in miles from Vonore, access to hay equipment, percentage of land previously cropped). Farmers that were selected into the program may be bias toward continuing switchgrass production. To account for potential bias, a selection equation describing how the granting agency assigned contracts to farmers who applied is described below:

$$y_i^* = sc_i\theta + \varepsilon_i, \tag{9}$$

where y_i^* is a latent variable that summarizes the granting agency's evaluation of the farmer's ability to succeed when growing switchgrass as a dedicated energy crop (this distribution of y_i^* can be positive or negative); sc_i contains variables associated with the selection criteria to distribute switchgrass contracts among farmers, determined by the granting agency (e.g., mileage to the ethanol facility, the number of acres farmers were willing to commit to the program); θ is a vector of parameters associated with the selection variables, and ε_i contains information about all other factors that affected the decision of the granting agency to assign a contract, but were not captured by the factors contained in the selection criteria (e.g., farmers' reputations among county agents, and other farmers). The behavioral intentions described in equation (8), BI, will only be observe if $y_i^* > 0$—the farmer received a positive evaluation from the granting agency on his or her ability to succeed growing switchgrass.

Chapter 4: Methods and Procedures

Primary Data

The data used in this study were collected in two stages during 2009. The first stage included semi-structured interviews with producers participating in the UTBI project. Two researchers and one Extension Switchgrass Specialist were also interviewed. These interviews were used to identify common beliefs about switchgrass production as a dedicated energy crop. The beliefs or ideas reported most frequently by the interviewees were then included in the survey questionnaire used in stage two to interview contracting producers in 2009 (N = 40).

The second stage of data collection included a targeted survey of the 40 farmers under contract with the UTBI project in 2009; 38 of the 40 producers responded to the second tier survey (95% response rate). Surveys were conducted through personal interviews. Before conducting the survey, farmers were informed about the objectives of the survey and their right to refuse to participate.

The survey asked questions about a farmer's education, age, experience, net household income, percentage of household income from farming, and acres of harvested cropland (Appendix B). Respondents were also asked about their expectations and beliefs about the development of a switchgrass feedstock market. The TPB section of the questionnaire included five pairs of questions to measure attitudes; five pairs of questions to measure subjective norms; two pairs of questions to measure perceived behavioral controls; and a question about the producer's intention to continue growing switchgrass as a dedicated energy crop following the expiration of their current contract. In the context of the behavioral intentions evaluated in this study, a direct measure of attitudes towards the continuation of switchgrass production following contract expiration may be inappropriate, given the multiple potential outcomes that may result

from switchgrass production (e.g. increase and stabilization of income, reduction of erosion, and diversification of farm). For example, including a general question that asks farmers whether they believe that growing switchgrass is good/bad, or beneficial/harmful, may be difficult to answer because of the potential multiple outcomes and the generality of these types of questions. Therefore, an attitude index was constructed by adding the different behavioral beliefs weighted by their evaluation measures as:

(10) $Attitudes = \mathrm{Q6} \times \mathrm{Q16} + \mathrm{Q7} \times \mathrm{Q14} + \mathrm{Q8} \times \mathrm{Q15} + \mathrm{Q9} \times \mathrm{Q12} + \mathrm{Q10} \times \mathrm{Q13},$

where $Attitudes$ is the attitude index. Questions 6, 7, 8, 9, and 10 ($\mathrm{Q6}, \mathrm{Q7}, \mathrm{Q8}, \mathrm{Q9}, \mathrm{Q10}$), as described in Table 2, capture farmers' beliefs about switchgrass production increasing and stabilizing profits, increasing but not stabilizing profits, stabilizing but not increasing profits, improving the allocation of equipment, time resources during the off season, and diversifying the farm operation, respectively. All Tables and Figures are presented in the Appendix A. Questions 16, 14, 15, 12, and 13 ($\mathrm{Q16}, \mathrm{Q14}, \mathrm{Q15}, \mathrm{Q12}, \mathrm{Q13}$) measure beliefs about the outcomes discussed in questions 6, 7, 8, 9, and 10. For example, the outcome of stabilizing and increasing profits due to switchgrass production (question 6) has a corresponding evaluation question (question 16) where the farmer states how important it is for him/her to increase and stabilize profits, ranging from "not important" to "very important". All behavioral beliefs (outcomes) with their corresponding evaluation measures were combined to estimate attitudes toward continuing to grow switchgrass as a dedicated energy crop.

Subjective norms may not be accurately captured by a direct measure, given the different groups that may influence behavioral intentions, such as family, neighbors, and media (Lynne et al., 1995). For example, including a general question that asks farmers about the importance of all other individuals' or groups' opinions in their production decisions regarding switchgrass

may be difficult to answer. Therefore, a subjective norm index, similar to the one built for attitudes, was developed as follows:

$$(11) SubjectiveNorm = \mathrm{Q22} \times \mathrm{Q42} + \mathrm{Q23} \times \mathrm{Q43} + \mathrm{Q24} \times \mathrm{Q44} + \mathrm{Q25} \times \mathrm{Q45} + \mathrm{Q26} \times \mathrm{Q46},$$

where SubjectiveNorm is the subjective norm index. Questions 42 through 46 $(\mathrm{Q42}, \mathrm{Q43}, \mathrm{Q44}, \mathrm{Q45}, \mathrm{Q46})$, as described in Table 2, capture farmers' beliefs about family, other farmers, County Extension agent, the media, and UT Extension Switchgrass Specialist opinions about switchgrass production, respectively. Questions 22 to 26$(\mathrm{Q22}, \mathrm{Q23}, \mathrm{Q24}, \mathrm{Q25}, \mathrm{Q26})$ capture importance of these individuals' opinions when making production decisions. All normative beliefs, with their corresponding motivation to comply measures, were combined to estimate the influence of subjective norms on intentions to continue growing switchgrass as a dedicated energy crop.

Indirect measures of perceived behavioral controls were used similarly to the ones estimating attitudes and subjective norms:

$$(12)\ PercievedBehavioralControl = \mathrm{Q27} \times \mathrm{Q35} + \mathrm{Q31} \times \mathrm{Q39},$$

where PercievedBehavioralControl is the perceived behavioral control index. Questions 27 and 31$(\mathrm{Q27}, \mathrm{Q31})$, as described in Table 1, measure farmers' beliefs about factors that may influence the likelihood of an individual continuing to grow switchgrass as an energy crop following contract expiration (i.e., equipment break downs and weed problems associated only with switchgrass production). Questions 35 and 39 $(\mathrm{Q35}, \mathrm{Q39})$ capture farmers' perceptions about the ability to control equipment breakdowns and weed problems potentially associated with switchgrass production, respectively. All control beliefs, with their corresponding control/power measures, were combined to estimate perceived behavioral controls potentially affecting intentions to continue growing switchgrass as a dedicated energy crop.

Switchgrass producers were asked to rank from 1 to 7 (1 = "unlikely" and 7 = "likely") their intention to continue producing switchgrass as a dedicated energy crop after their current contract expired. For the purpose of this study, intentions were grouped into two groups, "high" intentions and "low" intentions. The classification of the intention variables in two groups was derived from observing the distribution of observation among the different Likert scale intentions categories (Figure 1). The sample of switchgrass farmers was concentrated in the 1 and 2 categories and the 5, 6 and 7 categories (i.e., upper and lower values of the scale). Very few farmers reported intentions in the middle of the scale (i.e., 3 and 4), and no farmers marked 3 as their evaluation of intentions to continue growing switchgrass. The farmers that reported their intentions as a 4 were categorized with the lower values of the scale (1 and 2). There were two intentions variables constructed based on different definitions of "high" and "low" intentions (i.e., $BI1$ and $BI2$) (Table 2). All other TPB questions were scored by asking respondents to answer a seven-point Likert scale ranging from "strongly disagree" to "strongly agree", "unlikely" to "likely", "not important" to "very important", or "rarely" to "frequently", depending on the question or statement discussed.

A measure of the effort (i.e., $Effort_{is}$) a farmer applied to growing switchgrass as a dedicated energy crop was constructed base on the Switchgrass Extension Specialists' (i.e., Jon Walton and Ken Goddard) evaluations of a farmer's effort on producing switchgrass. A five question survey (see Appendix B) was sent to the switchgrass specialists via e-mail asking questions regarding actions taken by the switchgrass farmers included in the sample to grow switchgrass as a dedicated energy crop. The questionnaire presented 5 statements regarding farmer (1) willingness to listen to the switchgrass specialists, (2) enthusiasm to grow switchgrass, (3) ability to plan and follow appropriate switchgrass production deadlines, (4)

ability to keep track of details that would guarantee a successful switchgrass crop, and (5) ability to act intuitively when identifying factors that may put the success of the switchgrass crop at risk. Each farmer was ranked in all five areas (i.e., willingness to listen, enthusiasm, planning, performance ability, and intuition) using a 1 to 7 Likert scale, where 1 represents strongly disagree and 7 represents strongly agree. For example, if the specialists believed that a farmer did not listen carefully to the specialist's instructions or was not willing to learn from them, the specialists marked a 1 (i.e., strongly disagree) for the statement, "*The farmer is willing to listen/learn from the switchgrass specialists*". Scores for each of the five statements were summed to obtain a total measure of effort for each farmer. It was assumed that higher sums reflect higher effort applied to growing the crop. An average of the total measures of effort provided by the two Switchgrass Extension Specialists was used to obtain a final measure of $Effort_{is}$ (Table 2).

Additionally, information for the selection equation presented in (9) was provided by Genera Energy LLC. The Genera data set summarized information about the 79 farmers who applied to contract in 2008 and 2009. The variables contained in the data set are associated with the questions asked in the application form. The application form requested information about: 1) average distance in miles from the location(s) where they would plant switchgrass to Vonore ($Mileage$), 2) ownership of land where the farmer planned to grow switchgrass, 3) inside storage availability ($StorageInside$), 4) whether the farmer owned hay equipment ($Baler$), 5) whether the farmer had any previous experience growing and harvesting forage grass ($PreviouslyHarvest$), 6) whether the farmer was currently growing and harvesting forage grass ($Growing$), and 7) acres previously cropped as a percentage of the total acres they were willing to commit to switchgrass production ($LandCropped$) (Table 2).

Heckman Selection Probit Estimation Procedure

The selection process of farmers to contract with the granting agency to produce switchgrass is captured by y_i^* in equation (9). The evaluation of farmer's ability to produce switchgrass as a dedicated energy crop is not observed, but the final decision of granting a switchgrass contract to a farmer is observed such that:

$$y_i = \begin{cases} 1 & if \quad y_i^* > 0 \\ 0 & otherwise \end{cases} \tag{13}$$

where $y_i = 1$ if a producer was granted a contract and $y_i = 0$ otherwise.

Intentions to continue growing switchgrass as a dedicated energy crop were framed under the random utility model as described in equation (7), where a farmer will have intentions to continue producing switchgrass if the difference between the utility from continuing to grow switchgrass and the utility from not continuing to grow switchgrass is positive (i.e., $\mu_{is} > 0$). The variable μ_{is} is an unobserved latent variable, but farmers' intentions to continue growing switchgrass as a dedicated energy crop after their contract expires (BI) can be evaluated such that:

$$BI = \begin{cases} 1 & \text{if } U_{is} - U_{ins} = \mu_{is} > 0 \\ 0 & \text{if } U_{is} - U_{ins} = \mu_{is} \leq 0 \end{cases} \quad | \, y_i > 0 \tag{14}$$

where $BI = 1$ if a producer has intentions to continue growing switchgrass and $BI = 0$ otherwise.

Under the assumption that the random component of the selection equation (ε_i) is distributed normal with $\mu = 0$ and $Var(\varepsilon_i) = 1$, the relationship between equations (9) and (13) yields:

$$P_c = \Pr(y_i = 1) = \Pr(\varepsilon_i > -(sc_i'\theta)) = 1 - \Phi_c\big(-(sc_i'\theta)\big), \tag{15}$$

where P_c is the probability of obtaining a contract to grow switchgrass as a dedicated energy crop and Φ_c is the cumulative normal distribution function for ε_i. The symmetric qualities of the standard normal distribution can be used to show that:

$$1 - \Phi_c\left(-(sc_i'\theta)\right) = \Phi_c\left((sc_i'\theta)\right) \tag{16}$$

Therefore the probability of obtaining a contract with the granting agency can be represented as:

$$P_c = \Phi_c\left((sc_i'\theta)\right) \tag{17}$$

Given the probabilities stated in equations (15) and (17), the sample likelihood function can be written as:

$$L = \prod_{y_i=1} \Phi_c\left((sc_i'\theta)\right) \prod_{y_i=0} \Phi_c\left(-(sc_i'\theta)\right) \tag{18}$$

Assuming that random errors of the behavioral intentions equation (ε_i^*) are distributed standard normal:

$$\begin{aligned} P_s &= \Pr(BI = 1 | y_i = 1) = \Pr(\mu_{is} > 0 | y_i = 1) \\ &= Pr(\varepsilon_i^* > -(Z_s\alpha_s) | 1 - \Phi_c\left(-(sc_i'\theta)\right)) \\ &= [1 - \Phi_s\left(-(Z_s\alpha_s)\right)] | \, 1 - \Phi_c\left(-(sc_i'\theta)\right) \end{aligned} \tag{19}$$

where P_s is the probability of intentions to continue growing switchgrass and, therefore, the probability of actually continuing to grow switchgrass as a dedicated energy crop—under the TPB approach intentions are considered to be accurate predictors of actions; Φ_s is the cumulative distribution function for ε_i^*; and:

$$Z_s\alpha_s = x'_{is}\beta_s - x'_{ins}\beta_{ns} + (\sum_{k=1}^{n_k} b_{ik}e_{ik})\delta_s - \delta_{ns} + (\sum_{j=1}^{n_j} n_{ij}m_{ij})\lambda_s - \lambda_{ns} + (\sum_{l=1}^{n_l} p_{il}c_{il})\eta_s - \eta_{ns} \tag{20}$$

The symmetric qualities of the standard normal distribution can be used to show that:

$$1 - \Phi_s\left(-(Z_s\alpha_s)\right) = \Phi_s\left((Z_s\alpha_s)\right) \tag{21}$$

Using equations (19) and (21), the conditional probability of intentions to continue growing switchgrass can be written as:

(22) $$P_s = \Phi_s\big((Z_s\alpha_s)\big)|\Phi_c\big((sc_i'\theta)\big)$$

The sample likelihood function for intentions to continue growing switchgrass can be written as:

(23) $$L = \prod_{BI=1|y_i=1} \Phi_s\big((Z_s\alpha_s), \rho\big) \prod_{BI=0|y_i=1} \Phi_s\big((-Z_s\alpha_s), -\rho\big),$$

where ρ is the correlation coefficient between ε_i^* and ε_i. ρ will ultimately measure the strength of the relationship between the error term for the contract equation and the error term for the intentions equation.

The conditionality illustrated in equation (23) exists because intentions to continue growing switchgrass can only be expressed by farmers who already have a contract with the granting agency. If $\rho \neq 0$, the estimated parameters of equations (7) and (9) can be accomplished by using a bivariate probit model with a sample selection. Heckman (1976) developed the two-step selection procedure to account for selection bias where a censored dependent variable, intentions to continue growing switchgrass, is observed. Selection bias is measured in terms of the level of correlation between the error terms of the equations. If $\rho = 0$, no significant evidence of selection bias exists, and equations (7) and (9) can be estimated separately from their respective populations with individual probit models.

Development of the Empirical Model

The Intentions Equation

The empirical model for behavioral intentions to continue producing switchgrass after contracts expire is specified as:

(24) $$BI_i = \beta_0 + \beta_1 Effort_{is} + \beta_2 Age_i + \beta_3 Acres_i + \beta_4 Exp.Non.Tradtional.Crops_i + \delta Attitudes_i + \lambda SubjectiveNorm_i + \eta PercievedBehavioralControl_i + \varepsilon_i,$$

where $Effort$ captures information about the farmer's effort in producing switchgrass as a dedicated energy crop. $Effort$ is associated with the component x_{is} in equation (7). The vector x_{is} was hypothesized to include the attributes associated with switchgrass production that are unique for each farmer given farm characteristics and farmer management skills (e.g., expected profits from switchgrass production, effort require to grow switchgrass). Expected profits from switchgrass may be calculated by multiplying price per acre (i.e., under the first round of contracts farmers were paid $450 per acre) by the number of acres of switchgrass grown and subtracting the cost of production. This estimation of expected profits may not be accurate given that 85% of the switchgrass farmers in 2009 expected the conditions of the switchgrass contract to change. The revenue component from the expected profits is calculated not only on a per acre basis (i.e., $450/acre times the number of acres of switchgrass) for the first year, but also on a per ton basis for years two and three if they intended to continue growing switchgrass under contract with Genera Energy LLC, according to the new contract conditions. Historical data on switchgrass yields and cost structure for each farm considered in this study were not available. Therefore, expected profits from growing switchgrass, and expected returns from not growing switchgrass were not use in this study. Age_i is the age in years of farmer i; $Acres_i$ represents the number of acres farmer i was willing to commit to switchgrass production when they applied to obtain a contract with the granting agency; $Exp.Non.Traditional.Crops_i$ is a subjective variable which represents the farmer's experience in growing crops that were non-traditional to the East Tennessee area such as sunflowers and canola (i.e., $Exp.Non.Traditional.Crops_i = 1$ if they had grown a non-traditional crop in the past, 0 otherwise). $Attitudes_i$, $SubjectiveNorm_i$, and $PercievedBehavioralControl_i$ are indexes that measure the

determinants of behavioral intentions according to the TPB approach (see Tables 1 and 2 for a complete explanation of all variables).

The Contract Equation (Selection Equation)

The empirical model for the selection equation described in (9) is specified as:

$$(25)\quad y_i = \theta_0 + \theta_1 PreviouslyHarvest_i + \theta_2 LandCropped_i + \theta_3 Mileage_i + \theta_4 Baler_i + \theta_5 Growing_i + \theta_6 Owned_i + \theta_7 StorageInside_i + \theta_7 Acres_i + \varepsilon_i$$

where y_i equals one if the farmer was granted a switchgrass contract in 2008 and/or 2009, and zero otherwise; $PreviouslyHarvest_i$ equals one if the farmer had previous experience growing and harvesting forage grass, 0 otherwise; $LandCropped_i$ equals acres previously cropped as a percentage of the total acres a farmer was willing to commit to switchgrass production; $Mileage_i$ represents average distance in miles from the location(s) where the farmer planted switchgrass to Vonore, TN; $Baler_i$ equals one if they had a hay baler, and zero otherwise; $Growing_i$ takes the value of one if the farmer was currently growing and harvesting any forage grass, zero otherwise; $Owned_i$ represents the percentage of own fields the farmer was willing to commit to switchgrass production; $StorageInside_i$ equals one if the farmer had access to inside storage facilities on his/her farm; and $Acres_i$ represents the number of acres the farmer was willing to commit to switchgrass production (see Tables 1 and 2 for a complete explanation of all variables).

Hypotheses

The Intentions Equation

Farmer and farm characteristics hypothesized to affect behavioral intentions to continue growing switchgrass as a dedicated energy crop included age and farm size. As a farmer's age (Age_i) increases his/her planning horizon decreases. Older farmers may be less likely to invest

resources in continuing the production of a crop for which a market has not been developed, or a crop with which they are not familiar (Jensen et al. 2006). In general, adoption literature in the context of agriculture finds that age is negatively associated with technology adoption (Hattam, 2006; McNamara et al, 2004; Roberts et al., 2004; Feder, Just, and Zilberman, 1985). The number of acres a farmer was willing to commit to switchgrass production ($Acres_{i_i}$) when applying for a contract can have a positive or negative impact with intentions to continue growing switchgrass as a dedicated energy crop. A larger number of acres a farmer was willing to commit to switchgrass production when applying for a contract may reflect greater ability to assume the risk of growing a new crop with no market and, therefore, the more likely the farmer is to intend to continue with this risky endeavor for at least one more period, or until a market is developed. In contrast, if a farmer experiences high losses after he or she was willing to commit a large number of acres to switchgrass production, and obtained a contract to grow switchgrass for all the acres, then he or she would be less likely to continue switchgrass as a dedicated energy crop. Additionally, if a farmer had grown non-traditional crops in the past ($Exp.Non.Tradtional.Crops$), he/she may be more likely to continue growing switchgrass based on a positive previous experience with non-traditional crops or he/she may be less likely to continue growing switchgrass based on a negative previous experience with non-traditional crops. This variable was introduced as suggested by the TPB approach, where intentions may be influenced by previous experience (Ajzen, 2001). Effort ($Effort$) in growing switchgrass—a measure of management skills and effort applied to growing this crop—is expected to have a positive impact on intentions to continue growing switchgrass as a dedicated energy crop. Farmers that applied more effort to producing switchgrass under the previous and have better management skills are expected to be more successful in growing the crop, and the farmer would

be expected to receive higher profits once a market is developed. Additionally, farmers may be more pessimistic about a market developing which would lead to less effort applied to the switchgrass crop and ultimately a negative impact on intentions to continue growing switchgrass.

Attitudes, subjective norms and perceived behavioral control were hypothesized to affect a farmer's intentions to continue growing switchgrass as a dedicated energy crop. Attitudes towards a behavior, described as an individual's evaluation (either positive or negative) towards the performance of that particular behavior, are hypothesized to have a positive influence on intentions to continue growing switchgrass as a dedicated energy crop. If the farmer believes that continuing to grow switchgrass will increase and/or stabilize income, improve the use of equipment and time resources during the off season, and diversify the farm operation (i.e., important goals for his/her farm operation), he/she would be more likely to continue growing switchgrass. Subjective norms, defined as social acceptance or rejection of a particular behavior, are hypothesized to have a positive impact on intentions to continue growing switchgrass. If individuals who may affect a farmer's production decisions (e.g., family, Extension personnel, and other farmers) believe that a long-term commitment to produce switchgrass as a dedicated energy crop is "good", the farmer may be more likely to have positive intentions to continue growing switchgrass as a dedicated energy crop. Perceived behavioral control, defined as an individual's perception of the ease or difficulty of performing a behavior, is hypothesized to have a positive influence on intentions to continue growing switchgrass as a dedicated energy crop. The more control the farmer perceives having over factors he/she thinks may prevent or permit the continuation of switchgrass (e.g., weed control, equipment breakdowns associated with switchgrass production), the more likely the farmer is to continue growing switchgrass as a dedicated energy crop.

The Contract Equation

The variables used to predict the likelihood of obtaining a contract to produce switchgrass with the granting agency were the ones set in the application form by Genera Energy LLC. If the applicant had previous experience growing and harvesting forage grass, it was expected that growing and harvesting switchgrass would be easier for this individual. Therefore, experience with forage grass ($PreviouslyHarvest$) was expected to be positively related with the probability of obtaining a contract. Acres previously cropped as a percentage of the total acres a farmer was willing to commit to switchgrass production ($LandCropped$) was expected to have a positive impact on the probability of obtaining a switchgrass contract. It was assumed that if a field had been previously cropped there was a higher probability that this field had received more intensive weed control compared to a field that has not been cropped in the past. It was also expected that farms closer to the biorefinery in Vonore, TN would have lower costs for the granting agency to transport the switchgrass from the field to the biorefinery. It was expected that the distance in miles from the farm to Vonore ($Mileage$) would be negatively related with the likelihood of obtaining a switchgrass contract. Similar to the expected impact of the variable capturing previous experience growing and harvesting forage grass, it is expected that a farmer who is currently growing and harvesting forage grass ($Growing$) will have a higher probability of obtaining a switchgrass contract.

Model Estimation

Equations (24) and (25) were estimated using maximum likelihood. Two models were estimated for the behavioral intentions equation presented in equation (24). The first model used $BI1$ as the dependent variable, and the second model used $BI2$ as the dependent variable (Table 1). The two models were compared to evaluate for the robustness of the results to the

construction of the variable measuring intentions to continue growing switchgrass as a dedicated energy crop. A Wald test was performed to test the null hypothesis that $\rho = 0$. Overall significance of the model was tested using a likelihood ratio test.

Exogeneity Tests

The inclusion of an effort variable in the estimation of the intentions to continue switchgrass production equation could create endogeneity problems. The effort applied to growing switchgrass may be related to the intentions to continue growing the crop after contracts expire. If a farmer is not intending to grow switchgrass after his/her contract expires, he/she might just put the minimum effort to grow the crop and follow requirements to obtain the $450/acre stipulated in the first round of contracts. In contrast, intentions to continue growing switchgrass may also be determined by the effort a farmer puts in growing the crop. As hypothesized above, the higher the effort a farmers applies to growing switchgrass, the more successful the farmer will be in growing the crop, and the higher the profits he would receive once a market is developed. Additionally, the variable ($Effort$) was developed in June of 2010 as compared to the intentions to continue producing switchgrass which were observed in the fall of 2009. Therefore, effort ($Effort$) was hypothesized to be potentially endogeneous.

Testing for exogeneity of this variable was accomplished using a procedure outlined by Amemiya (1979) for the Nelson-Olsen model (1978), and presented in Maddala (1983). In this procedure, a two-stage method is used to estimate the intentions and effort equations. In the first stage, effort ($Effort$) is regressed against all variables included in the intentions equation (Age,$Exp.Non.Tradtional.Crops$, $Attitudes$, $SubjectiveNorm$, $PercievedBehavioralControl$, $Acres$) and the variables hypothesized to be determined effort (Age, P*ercentage of 2008 taxable household income from farming)* by OLS. The intentions

variable (BI) is also regressed against all exogenous variables included in the effort equation and the intentions equation by the logit method. In the second stage, the equation for effort ($Effort$) is estimated using the intentions variable obtained from stage one ($\widehat{BI}$) as an independent variable, and the equation for BI is estimated using the effort variable obtained from stage one ($\widehat{Effort}$) as an independent variable. Finally, the statistical significance for the parameters associated to the estimated intentions variable ($\widehat{BI}$), and the estimated effort variable ($\widehat{Effort}$) is tested for statistical significance. The standard errors for the parameters associated to these variables are obtained from the estimated asymptotic covariance matrix (Amemiya, 1979). Failure to reject the null hypothesis of no significance of $\widehat{Effort}$ provides evidence that the effort variable is exogenous.

Multicollinearity Tests

Multicollinearity can compromise inferences by inflating variances estimates (Greene, 2003; Judge et al., 1988). Variance inflation factors were used to detect the presence of multicollinearity. Variance inflation factors were calculated using the squared multiple correlation coefficient from the regression of each explanatory variable on all other explanatory variables. As the degree of variation in each individual explanatory variable explained by all other explanatory variables increases, the value of the variance inflation factor increases. Variance inflation factors with a value greater than 10 may indicate the presence of collinearity in the data (Chatterjee and Price, 1991).

Chapter 5: Results

Descriptive statistics

On average, farmers with contracts to produce switchgrass were 58 years old and had farmed 33 years, derived 41% of their 2008 taxable household income from farming, and farmed 327 acres of cropland (Table 2). The farmers' age ranged from 28 to 83 and their years farming ranged from 2 to 78 years. The total cropland farmed by the farmers with switchgrass contracts ranged from 17 to 1,470 acres, and their 2008 taxable household income from farming ranged from 0% to 100%. All of the respondents had graduated from high school, or had earned high school equivalent degrees and 69% had earned an Associate degree or higher (Bachelor's degree or Graduate degree) (Figure 2). About 77% of the producers reported net household incomes lower than $150,000 (Figure 3). Nearly 35% of the respondents spent more than 55% of their time in non-farming activities and 38% spent more than 55% of their time managing other crops or livestock.

Descriptive statistics suggest that a large percentage of switchgrass producers intend to continue growing switchgrass as a dedicated energy crop after their current contracts expire. About 87% of the respondents rated their intentions to continue growing switchgrass as 5, 6 or 7 on a scale of 1 to 7, where 1 is "unlikely" and 7 is "likely" (Table 1). About 86% of the switchgrass farmers interviewed believed that it is "likely" for switchgrass production to increase and stabilize farming income: 33.3% of respondents rated this statement as 5, 25% rated it as 6, and 27.8% rated it as 7. About 20% of the producers interviewed believed that it is "likely" for switchgrass production to improve farm income but decrease farm income stability: 13.1% of respondents rated this statement as 5, 5.2% rated it as 6, and 2.6% rated it as 7. About 37% of the switchgrass farmers interviewed believed that it is "likely" for switchgrass production to stabilize

farm income but not increase farm income: 13.1% of respondents rated this statement as 5, 13.1% rated it as 6, and 10.5% rated it as 7. About 84% of the producers interviewed believe that is "likely" switchgrass would help them better allocate equipment and time resources during off-season time: 21.1% of respondents rated this statement as 5, 29% rated it as 6, and 34.2% rated it as 7. About 75% of the respondents believe that is "likely" that switchgrass production would help them diversify their farming operation: 11.1% of respondents rated this statement as 5, 19.4% rated it as 6, and 44.4% rated it as 7. Overall, producers were positive about continuing to grow switchgrass. This attitude may explain in part their relatively strong intentions to continue growing switchgrass after their contracts expire.

About 65% of the respondents agreed, with the statement, "*My family thinks that I should continue diversifying my farm with a dedicated energy crop"*; they rated this statement as 5, 6, or 7 on a scale from 1 to 7, where 1 is 'Strongly disagree" and 7 is "Strongly agree" (Table 1). Of the respondents, 32% thought that other farmers in the area perceived switchgrass production as beneficial for their farms (Table 1). About 70% of the switchgrass farmers interviewed agreed with the statements, "*My County Extension Agent thinks that I should continue diversifying my farm with a dedicated energy crop*" and "*The UT Extension Switchgrass Specialists think that I should continue diversifying my farm with a dedicated energy crop*". Only about 29% of the switchgrass farmers interviewed believed that the opinions of other farmers influenced their production decisions. When asked to complete the statement, "*The experience/opinions of other farmers about growing a new crop influence my production decisions*", 29% of the respondents marked 5, 6, or 7 on a scale from 1 to 7 where 1 is "Not at all" and 7 is "Very much" (Table 1). In contrast, about 86% of the switchgrass farmers interviewed considered UT Switchgrass Specialists' opinions to influence their production decisions (Table 1). About 84% of the

respondents agreed, with the statement, "*I have seen in the media (TV, radio, internet, paper, magazines, etc.) that farmers growing energy crops will help alleviate the energy crisis"*; they rated this statement as 5, 6, or 7 on a scale from 1 to 7, where 1 is 'Strongly disagree" and 7 is "Strongly agree" (Table 1). Overall, switchgrass farmers perceived that other individuals who influence their production decisions (e.g., family and Extension personnel) have a positive attitude toward their behavioral intentions to continue growing switchgrass. As stated by the TPB, intentions to pursue a behavior are determined in part by social acceptance of the behavior. Social acceptance appears to be one of the factors explaining the relatively strong intentions to continue growing switchgrass.

Questions associated with the perceived behavioral control component asked about two potential factors that may obstruct producers' intentions to continue switchgrass production after their contracts expire: 1) equipment breakdowns and 2) weed problems associated with switchgrass production. About 78% of the farmers interviewed used up to 13% of the time working on their farm on equipment breakdowns associated with switchgrass, and about 70% of them agreed, to some extent, with the statement, "*Time spent on equipment break downs associated with switchgrass production will not prevent me from continuing to produce switchgrass*" (Table 1). Additionally, although weed problems associated with switchgrass were frequently observed by 50% of the respondents, 54% of the respondents agreed with the statement, "*Weed problems affecting switchgrass after the crop is established will not prevent me from continuing to produce switchgrass*" (Table 1). Results suggest that weed problems are observed by most growers but that they feel that they have control over this factor. Additionally, equipment breakdowns associated with switchgrass are not perceived as a major factor influencing the decision to continue growing switchgrass. Perceived control over equipment

breakdowns and weed problems associated with switchgrass production may explain the relatively strong intentions of the producers interviewed to continue growing switchgrass as a dedicated energy crop.

On average, switchgrass farmers agreed with the statement, "*Having Private Companies providing Extension support is important to continue growing switchgrass*"; the average score for this statement was 5.9 on a scale from 1 to 7, where 1 is "Strongly disagree", and 7 is "Strongly agree" (Table 3). Nonetheless, respondents generally disagreed with the statement, "*Private Companies negotiating directly with farmers for contracts will provide Extension support*" (e.g., average score of 3.6). Although none of these statements appeared to be correlated with intentions to continue growing switchgrass after contracts expired, it is interesting to note that, on average, switchgrass farmers perceived Extension support as an important factor when making decisions about growing switchgrass as a dedicated energy crop, regardless of the trust they have about private investors actually providing this kind of support in the future.

Table 3 shows the Spearman's rank correlation coefficients measuring levels of association between intentions to continue growing switchgrass after contracts expire and attitudes, normative beliefs, and perceived behavioral control. Despite the fact that attitudes are positive toward the perceived benefits of switchgrass production as a dedicated energy crop (e.g., it will stabilize and increase average farming income, it will stabilize but not increase average farming income, it will increase but not stabilize average farming income, it will allow diversification, and it will allow farmers to allocate equipment and time resources more efficiently during the off season), correlation between attitudes and intentions to continue growing switchgrass as a dedicated energy crop after contracts expire, although positive, was not

significant (e.g., Spearman's rank correlation coefficient of 0.3 and $p>0.1$). Also important to the formation of intentions is the perceived influence of others (e.g., family and Extension personnel) in the decision making process. A strong positive correlation between perceived social pressure (subjective norms) and intention to continue growing switchgrass was identified (e.g., Spearman's correlation coefficient of 0.4 and $p<0.05$), suggesting that the opinions of others about switchgrass production may influence farmers' decisions to continue growing switchgrass as a dedicated energy crop. Finally, the correlation between perceived control over the challenges producers could face producing switchgrass (e.g., weed management and equipment breakdowns) and intentions to continue growing switchgrass was not statistically significant ($p>0.1$). This result suggests that production challenges such as equipment breakdowns and weed problems may not play a major role in the decision to continue growing switchgrass after contracts expire, given that farmers perceived they have the ability to overcome these challenges.

Associations between behavioral intentions to continue growing switchgrass and other beliefs and demographic characteristics were also evaluated. Correlation between expectations about the development of a switchgrass market in five years and the intention to continue growing switchgrass as an energy crop was positive and significant (e.g. Spearman's rank correlation coefficient= 0.4 and $p<0.05$). Demographic characteristics (e.g., age, experience, percentage of farm income, and number of acres in cropland) were not correlated with intentions to continue producing switchgrass after the current contract expires. This result suggests that there may not be a specific profile of respondents whose intentions are demographically different from the rest of the switchgrass farmers interviewed.

Econometric Results

Variance Inflation Factors (VIF) were below 2 for all variables included in both ($BI1$ and $BI2$) Heckman Sample Selection models (Tables 4 and 5). This result suggests that inferences made from the estimated coefficients are not likely affected by inflated standard errors.

The Wald test indicated failure to reject the null hypothesis that $\rho = 0$ for both models (*Wald (1)* = 0.58, p= 0.44 for $BI1$ and *Wald (1)* = 0.40, p = 0.52 for $BI2$) in the estimation of the intentions and contract equations (Tables 4 and 5). Thus, individual binomial probit models for the intentions and contract equations are appropriate. The Likelihood Ratio χ^2 test for the contract equation (Table 6) was significant at the 10 % level ($LR\chi^2(8) = 14.01$ and $p = 0.08$). The Likelihood Ratio χ^2 test that at least one of the predictors' regression coefficients is not equal to zero was not significant for both the behavioral intentions equations using $BI1$ and $BI2$ as the dependent variables (Table 7 and 8). The contract model correctly predicted 71% of the responses, the intentions model with $BI1$ as the dependent variable correctly predicted about 80% of the responses, and the intentions model with $BI2$ as the dependent variable correctly predicted about 86% of the responses. Tests failed to reject the hypothesis of statistical exogeneity of the effort variable ($Effort$) at the 5% level for the $BI1$ and the $BI2$ models (Table 9).

Contract Equation

Results from the contract equation are presented in Table 6. The percentage of acres a farmer was willing to commit to switchgrass production of total acres previously cropped ($LandCropped$) positively affected the probability that a farmer would be granted with a switchgrass contract. This result is consistent with the selection criteria developed by the granting agency. It is expected that land that had been previously cropped with row crops or pasture had a higher probability of more intensive weed control. More intensive weed control

facilitates the production of switchgrass. Therefore, the granting agency was more likely to grant switchgrass contracts to farmers who had a larger percentage of their acres previously cropped with a crop that required weed control. Other variables from the selection criteria were not statistically significant: distance to Vonore ($Mileage$), experience growing and harvesting forage grass ($PreviouslyHarvest$), access to a baler ($Baler$), percentage of fields own by the farmer (*Owned*), farmer currently growing and harvesting forage grass ($Growing$), access to inside storage ($StorageInside$), and number of acres farmers were willing to commit to switchgrass production ($Acres$). This result may be explained by the fact that most farmers who applied for contracts had similar characteristics based on the selection criteria (Table 1) and, therefore, other variables not presented in the contract equation were considered in making final decisions to grant farmers switchgrass contracts.

Intentions to Continue Growing Switchgrass as a Dedicated Energy Crop

Results from the intentions equations are presented in Tables 7 and 8. Subjective Norm ($SubjectiveNorm$) positively affected the probability of having intentions to continue growing switchgrass, using both $BI1$ and $BI2$ as the dependent variables. The significant variable had signs that agreed with a priori hypotheses. As theorized by the TPB approach, the higher the social acceptance of producing switchgrass, the higher the intentions are to continue growing switchgrass. Farmers perceive that individuals who are important to them when making production decisions (e.g., family, Extension personnel, and other farmers) have positive attitudes toward them engaging in a long-term commitment to produce switchgrass and therefore they are more likely to have highly positive intentions to continue growing switchgrass. This result is consistent with the results presented by Hipple and Duffy (2002) who suggested that the

alignment of the adoption of switchgrass as an energy crop with family beliefs would be critical for farmers to adopt switchgrass.

The variables included in the intentions equation, when using both $BI1$ and $BI2$ as the dependent variables were not significant. Age of the farmer (Age), previous experience growing non-tradition crops ($Exp.Non.Tradtional.Crops_i$), attitudes toward switchgrass production ($Attitudes_i$), the perceived control over the factors that may affect the production of switchgrass ($PercievedBehavioralControl_i$), the effort put into growing switchgrass ($Effort$), and the number of acres the farmer was willing to commit to switchgrass production when they applied to obtained a contract ($Acres$) did not significantly affected farmers' intentions to continue growing switchgrass.

Chapter 6: Summary and Conclusions

Farmers' intentions to continue growing switchgrass after contracts with the granting agency expire were analyzed as a function of observable farmer characteristics, attitudes, subjective norm, and perceived behavioral control (i.e. variables hypothesized to determine individuals' intentions under the Theory of Planned Behavior). Because having a contract to produce switchgrass is a prerequisite to expressing intentions to continue growing switchgrass after the contract expires, equations were estimated sequentially to provide a basis for comparing the variables hypothesized to affect obtaining a contract and intending to continue growing switchgrass after contracts expire.

The results from probit regressions suggest that the percentage of acres a farmer was willing to commit to switchgrass production of total acres previously cropped was critical to the granting agency in making the decision to grant a farmer a switchgrass contract. This result suggests that other factors than those included in the selection criteria were considered by the granting agency when selecting farmers to grow switchgrass. This result may be explained by the fact that the applicants for switchgrass contracts were very similar based on the selection criteria; therefore, the granting agency was forced to consider other factors to select farmers. Additionally, results suggested that social acceptance of switchgrass production by individuals who were important to farmers in making production decisions (e.g., family, Extension personnel, and other farmers) had a positive impact on farmers' intentions to continue growing switchgrass.

Results from this study suggest that community perceptions may have an important impact on farmers' intentions to make a long-term commitment to produce switchgrass. Educating community and Extension personnel may have a positive impact on farmers' decisions

to make long-term commitments to grow switchgrass, given that family and Extension personnel opinions seem to influence production decisions of current switchgrass producers. By educating family, Extension, and other individuals in the community, the switchgrass program may experience an increase in continued participation. The granting agency may consider conducting a community wide switchgrass educational program before the next round of switchgrass contracts are presented. Private investors may consider involving the community when contracting with farmers for switchgrass production to induce a long term-commitment for farmers to supply energy feedstocks. Private investors could benefit from tailoring programs towards the community as a whole. These results may also be important for policy makers. This information may aid in the design of strategies to encourage farmers to commit to the continued production of switchgrass.

Limitations

A limitation of this study is the small sample size. As a market for switchgrass develops and more farmers contract for the production of switchgrass, more information should be collected, and future econometric analyses could reveal more information about the effects of behavioral, social and perceived control beliefs, and other farm/farmer characteristics on farmers' intentions to make a long-term commitment to produce switchgrass.

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Appendix A: Tables 1–9 and Figures 1-3

Table 1. Description of Variables and Summary Statistics

Variable	Description	Mean
BI1	= 1 if respondents rated their intentions to continue producing switchgrass as a dedicated energy crop after their current contract expires as 5, 6, or 7 on a scale of 1 to 7, 0 otherwise	0.86
BI2	= 1 if respondents rated their intentions to continue producing switchgrass as a dedicated energy crop after their current contract expires as a 6 or 7 on a scale of 1 to 7, 0 otherwise	0.81
Age	Age of Farmer in years	57.48
Acres	Amount of Acres farmer is willing to commit to switchgrass production	56.93
Attitude	An index of respondents' attitudes toward switchgrass productions, constructed by adding different behavioral beliefs weighted by their evaluation measures. Ranges from 5 to 245	131.3
PercievedBehavioralControl	An index of a respondents' beliefs about factors that may influence the likelihood of an individual continuing to grow switchgrass, constructed by adding different perceived control beliefs weighted by their power of control factors. Ranges from 2 to 98	83.78
SubjectiveNorm	An index of a respondent's beliefs about specific individuals' (i.e. family members) opinions about switchgrass production, constructed by adding different normative beliefs weighted by their motivation to comply. Ranges from 5 to 245	110.91
Exp.Non.Traditional.Crops	= 1 if farmer had experience with nontraditional crops, zero otherwise	0.24
Effort	An average score of each switchgrass specialists' evaluation of the effort a farmer puts on producing switchgrass. Ranges from 5 to 35	28.42
Contract	= 1 if farmer received a switchgrass, zero otherwise	0.50
PreviouslyHarvested	= 1 if the farmer has grown and harvested forage grass, zero otherwise	0.94
LandCropped	Percentage of acres previously cropped from the total acres a farmer is willing to commit for switchgrass production	0.35
Mileage	Average mileage from fields to Vonore	25.52
Baler	= 1 if the farmer has access to a hay baler, zero otherwise	0.94
Growing	= 1 if the farmer is currently growing and harvesting a forage grass, zero otherwise	0.91
Owned	Percentage of fields that farmer is willing to commit to switchgrass production that he/she owns	0.83
StorageInside	= 1 if inside storage is available, zero otherwise	0.62

Table 2. Distribution of Responses on Likert Scale Questions on Behavioral Intentions and Components of the Cognitive Variables of Respondents.

Question	Likert scale (% farmers in each rank)						
Intentions							
	1=Unlikely	2	3	4	5	6	7 = Likely
Q.17*: I intend to continue growing switchgrass on my farm once my contract expires*	5.3	2.6	0.0	5.3	5.3	36.8	44.7
Attitude							
Behavioral Beliefs							
	1=Unlikely	2	3	4	5	6	7 = Likely
Q.6: *Continuing the production of switchgrass will improve my average profits, and will also increase the stability of those profits*	0.0	2.8	2.8	8.3	33.3	25.0	27.8
Q.7: *Continuing the production of switchgrass will improve my average profits, but will decrease the stability of those profits*	5.2	31.5	18.4	23.6	13.1	5.2	2.6
Q.8: *Continuing the production of switchgrass will stabilize my profits, but will not increase my average profits*	13.1	21.0	15.7	13.1	13.1	13.1	10.5
Q.9: *Continuing the production of switchgrass will allow me to allocate equipment and time resources more efficiently during the off season*	0.0	2.6	0.0	13.2	21.1	28.9	34.2
Q.10: *Continuing the production of switchgrass will allow me to diversify my farm*	2.8	13.9	0.0	8.3	11.1	19.4	44.4
Evaluation of Behavioral Beliefs							
	1=Not Important	2	3	4	5	6	7 = Very Important
Q. 12: *The ability to use equipment and time resources during the off season is important to improve the economic situation of my farm is*	0.0	2.6	13.2	18.4	18.4	23.7	23.7
Q.13: *To diversify my farm is*	5.6	5.6	5.6	11.1	8.3	19.4	44.4
Q.14: *To increase my average profits even if that represents lower stability in those profits is*	0.0	7.8	10.5	26.3	15.7	21.0	18.4
Q.15: *To stabilize profits even if it does not represent higher average profits is*	2.6	10.5	7.8	13.1	31.5	15.7	18.4
Q.16: *To stabilize and increase my profits is*	0.0	0.0	5.6	5.6	19.4	22.2	47.2

Table 2. Continued

Question	Likert scale (% farmers in each rank)						
	Subjective Norm						
	Normative Beliefs						
	1= Strongly Disagree	2	3	4	5	6	7 = Strongly Agree
Q.42: *My family thinks that I should continue diversifying my farm with a dedicated energy crop*	13.5	0	2.7	18.9	8.1	37.8	18.9
	1= Not Beneficial	2	3	4	5	6	7= Very Beneficial
Q.43: *Other farmers in my area think that diversifying my farm with a dedicated energy crop is*	10.8	10.8	10.8	35.1	8.1	18.9	5.4
	1= Strongly Disagree	2	3	4	5	6	7 = Strongly Agree
Q.44: *My County Extension Agent thinks that I should continue diversifying my farm with a dedicated energy crop*	5.4	2.7	0	13.5	27	27.6	29.7
Q.45: *The UT Extension Switchgrass Specialists think that I should continue diversifying my farm with a dedicated energy crop*	0	5.7	5.7	5.7	17.1	31.4	34.3
Q.46: *I have seen in the media that farmers growing energy crops will help to alleviate the energy crisis in the U.S.*	0	5.5	2.7	5.5	16.6	30.5	38.8
	Motivations to comply						
	1=Not at all	2	3	4	5	6	7 = Very much
Q.22: *The opinions of my family influences my crop production decisions*	26.3	15.8	10.5	7.9	10.5	15.8	13.2
Q.23: *The experience/opinions of other farmers about growing a new crop influence my production decisions*	44.7	7.9	10.5	7.9	10.5	18.4	0

Table 2. Continued

Question	Likert scale (% farmers in each rank)						
	Motivations to comply						
	1=Not at all	2	3	4	5	6	7 = Very much
Q.24: *My Extension agent's opinions influence my crop production decisions*	23.7	5.3	2.6	2.6	21.1	18.4	26.3
Q.25: *The UT Extension Switchgrass Specialist's opinions influence my crop production decisions*	2.8	5.6	2.8	2.8	11.1	30.6	44.4
Q.26: *The media influences my switchgrass production decisions*	35.1	16.2	18.9	13.5	13.5	2.7	0
Perceived Behavioral Control							
	Control Beliefs						
	1= 0%-13%	2	3	4	5	6	7 = 84% - 100%
Q.27: *Percentage of time, working on farm, spend with equipment break downs associated with only switchgrass production?*	78.4	13.5	2.7	2.7	2.7	0	0
	1=rarely	2	3	4	5	6	7 = frequently
Q.31: *How often do you observe weed problems associated with switchgrass*	5.4	2.7	13.5	8.1	16.2	21.6	32.4
	Power of Control Factors						
	1= Strongly Disagree	2	3	4	5	6	7 = Strongly Agree
Q. 35: *Time spent on equipment break downs associated with switchgrass production will not prevent for me to continue producing switchgrass*	2.7	5.4	8.1	13.5	13.5	27	29.7
Q.39: *Weed problems affecting switchgrass after the crop is established will not prevent for me to continue producing switchgrass*	10.8	13.5	8.1	10.8	21.6	21.6	13.5

Table 3. Descriptive Statistics and Correlation between TPB Variables, Market Development Outlets Variables, Personal Attributes, and Behavioral Intentions

Variable	Mean	Sd.	Spearman Correlation with Behavioral Intentions[a]
TPB Variables:			
Attitudes (Index, range 5 to 245)	131.3	37.2	0.3
Subjective Norm (Index, range 5 to 245)	110.9	43.7	0.3**
Perceived Behavioral Control (Index, range 2 to 98)	83.7	29.4	0.3
Market Development Outlets:			
The development of a switchgrass market in 5 years is (1= unlikely and 7= likely)	5.5	1.2	0.4***
Private Companies negotiating directly with farmers for contracts will provide Extension Support (1= strongly disagree to 7= strongly agree)	3.6	1.9	0.2
Having Private Companies providing Extension Support is important to continue growing switchgrass (1= strongly disagree to 7= strongly agree)	5.9	1.6	-0.1
Personal Attributes:			
Age	57.5	15.4	-0.1
Years Farming	32.8	20.0	0.1
Percentage of farm income	40.8	37.7	0.0
Cropland	327.1	382.4	-0.2

[a] Spearman's Correlation coefficient.
* $p < 0.1$, ** $p < 0.5$, and *** $p < 0.01$.

Table 4. Heckman Sample Selection Model Estimation of Intentions to Continue Switchgrass Production Given that Farmers were Granted a Switchgrass Contract (*BI*1 as measurement of intentions)

	Dependent Variable			
	*BI*1 (n = 38)		*Contract* (n = 79)	
Independent Variable	Coefficient[a]	Marginal Effect	Coefficient	Marginal Effect
Constant	-2.175		-0.992	
	(1.752)		(1.300)	
Age	0.033	0.002		
	(0.043)	(0.003)		
Acres	-0.001	-0.000	-0.001	-0.000
	(0.010)	(0.001)	(0.005)	(0.002)
Attitude	-0.001	-0.000		
	(0.020)	(0.001)		
PercievedBehavioralControl	-0.004	-0.000		
	(0.022)	(0.00086)		
SubjectiveNorm	0.017**	0.001**		
	(0.006)	(0.001)		
Exp.Non.Traditional.Crops	-0.190	-0.013		
	(3.655)	(0.268)		
Effort	0.156	0.011		
	(0.289)	(0.017)		
PreviouslyHarvested			0.287	0.111
			(1.151)	(0.434)
LandCropped			1.012***	0.403***
			(.353)	(0.140)
Mileage			-0.000	-0.000
			(0.017)	(0.006)
Baler			0.492	0.186
			(0.783)	(0.272)
Growing			0.270	0.105
			(1.038)	(0.395)
Owned			-0.293	-0.116
			(0.558)	(0.222)
StorageInside			-0.126	-0.050
			(1.423)	(0.566)
ρ	-0.94			
Wald Statistic (H_0:ρ=0)			0.58	
Log Likelihood			-56.63	

* p < 0.1, ** p < 0.5 and *** p < 0.01.

[a] Standard errors in parenthesis.

Table 5. Heckman Sample Selection Model Estimation of Intentions to Continue Switchgrass Production Given that Farmers were Granted a Switchgrass Contract (*BI*2 as measurement of intentions)

	Dependent Variable			
	*BI*2 (*n* = 38)		*Contract* (*n* = 79)	
Independent Variable	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Constant	-1.684		-0.896	
	(1.394)		(1.078)	
Age	0.012	0.001		
	(0.019)	(0.002)		
Acres	-0.001	-0.000	-0.001	-0.000
	(0.006)	(0.000)	(0.003)	(0.001)
Attitude	0.000	0.000		
	(0.006)	(0.000)		
PercievedBehavioralControl	0.000	0.000		
	(0.008)	(0.000)		
SubjectiveNorm	0.011**	0.001*		
	(0.005)	(0.000)		
Exp.Non.Traditional.Crops	-0.187	-0.020		
	(0.573)	(0.063)		
Effort	0.228	0.025		
	(0.191)	(0.019)		
PreviouslyHarvested			0.378	0.145
			(1.099)	(0.401)
LandCropped			1.028***	0.409***
			(0.346)	(0.137)
Mileage			-0.000	-0.000
			(0.011)	(0.004)
Baler			0.413	0.158
			(0.726)	(0.261)
Growing			0.194	0.076
			(0.859)	(0.333)
Owned			-0.302	-0.120
			(.554)	(0.220)
StorageInside			-0.180	-0.071
			(0.321)	(0.127)
ρ	-0.99			
Wald Statistic (H_0:ρ=0)			0.40	
Log Likelihood			-58.63	

** p < 0.5 and *** p < 0.01.

Table 6. Probit Regression for Contract model

	Dependent Variable	
	Contract (n = 79)	
Independent Variable	Coefficient	Marginal Effect
Constant	-0.694	
	(1.131)	
PreviouslyHarvested	-0.056	-0.022
	(1.162)	(0.461)
Acres	-0.001	-0.000
	(0.002)	(0.001)
LandCropped	0.873**	0.348**
	(0.375)	(0.149)
Mileage	-0.002	-0.000
	(0.012)	(0.004)
Baler	0.589	0.225
	(0.709)	(0.248)
Growing	0.552	0.213
	(0.858)	(0.310)
Owned	-0.614	-0.245
	(0.483)	(0.192)
StorageInside	0.067	0.027
	(0.334)	(0.133)
Log Likelihood function	-47.75	
Likelihood ratio statistic	14.01[a]	
Correctly predicted	70.89%	

[a] Likelihood ratio statistic is LR=2(log-likelihood unrestricted – log-likelihood restricted).
** $p < 0.5$.

Table 7. Probit Regression of Intentions to Continue Switchgrass Production (*BI*1 as measurement of intentions)

	Dependent Variable	
	*BI*1 (*n* = 38)	
Independent Variable	Coefficient	Marginal Effect
Constant	-2.851	
	(3.066)	
Age	0.035	0.004
	(0.029)	(0.003)
Acres	-0.003	-0.000
	(0.008)	(0.001)
Attitude	-0.002	-0.000
	(0.008)	(0.001)
PercievedBehavioralControl	-0.005	0.000
	(0.012)	(0.001)
SubjectiveNorm	0.018**	0.002*
	(0.009)	(0.001)
Exp.Non.Traditional.Crops	-0.227	-0.034
	(0.764)	(0.125)
Effort	0.212	0.029
	(0.315)	(.041)
Log Likelihood	-11.301	
Likelihood ratio statistic	6.11	
Correctly Predicted	80.00%	

* p < 0.1 and ** p < 0.5.

Table 8. Probit Regression of Intentions to Continue Switchgrass Production (*BI*2 as measurement of intentions)

	Dependent Variable	
	*BI*2 (n = 38)	
Independent Variable	Coefficient	Marginal Effect
Constant	-2.191	
	(2.622)	
Age	0.012	0.002
	(0.022)	(0.004)
Acres	-0.002	-0.000
	(0.008)	(0.001)
Attitude	-0.001	-0.000
	(0.008)	(0.001)
PercievedBehavioralControl	0.000	0.000
	(0.011)	(0.002)
SubjectiveNorm	0.013*	0.002*
	(0.008)	(0.001)
Exp.Non.Traditional.Crops	-0.282	-0.062
	(0.711)	(0.168)
Effort	0.274	0.056
	(0.258)	(0.050)
Log Likelihood	-13.50	
Likelihood ratio statistic	5.06	
Correctly Predicted	85.71%	

* p < 0.1 and ** p < 0.5.

Table 9. T-test of significance of Effort as an Exogenous Variable in the Intentions Model (*BI*1, and *BI*2 as measurements of intentions)

Model	t- statistic	Critical t statistic[c]
*BI*1 [a]	-0.35	1.86
*BI*2[b]	-0.35	1.86

[a] *BI*1 is equal one if respondents rated their intentions to continue producing switchgrass as a dedicated energy crop after their current contract expires as a 5, 6, or 7 on a scale of 1 to 7, 0 otherwise.
[b] *BI*2 equals one if respondents rated their intentions to continue producing switchgrass as a dedicated energy crop after their current contract expires as a 6 or 7 on a scale of 1 to 7, 0 otherwise if the farmer abandoned precision soil sampling and zero otherwise.
[c] Degrees of freedom for the *BI*1 and *BI*2 models were 8

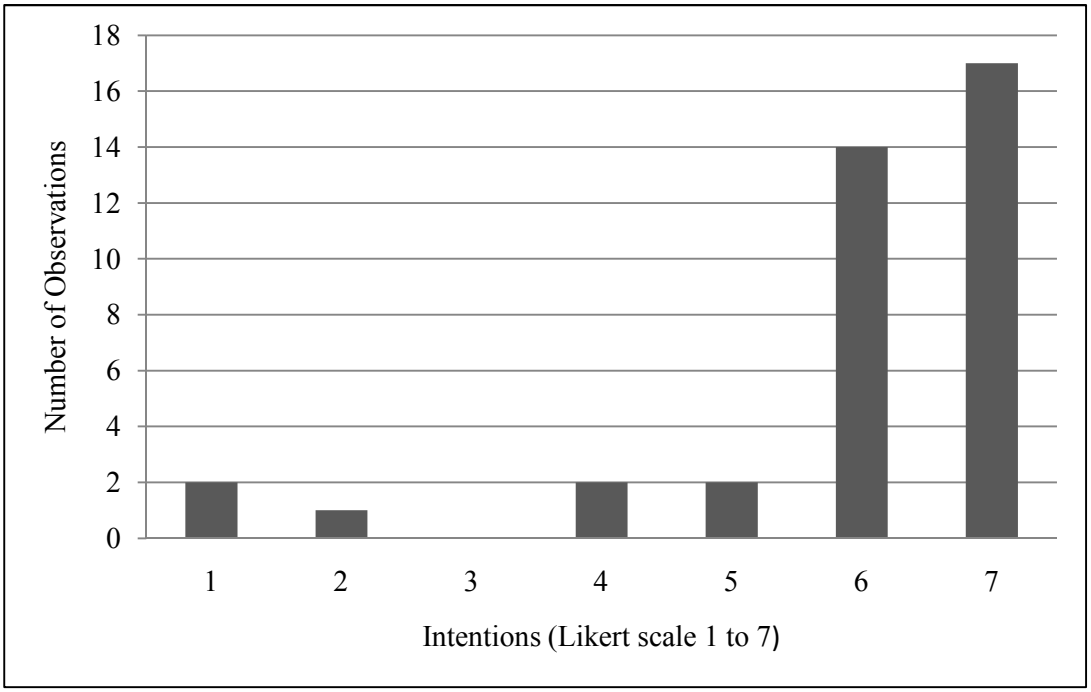


Figure 1. Distribution of Farmers According to Likert Scale Intentions Reponses

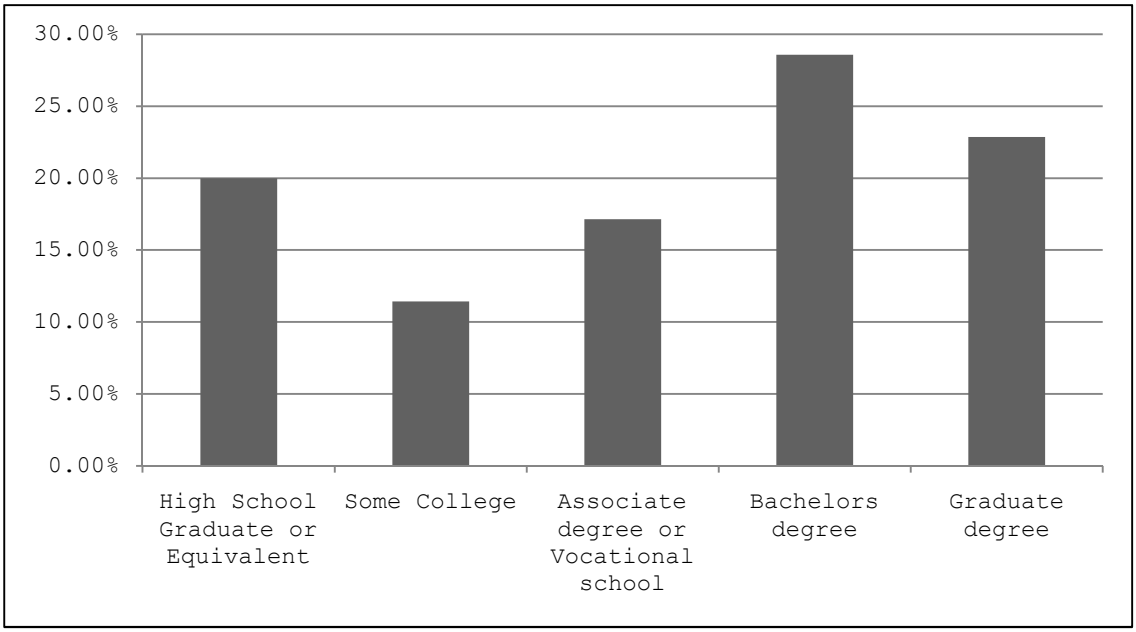


Figure 2. Educational Level of Respondents

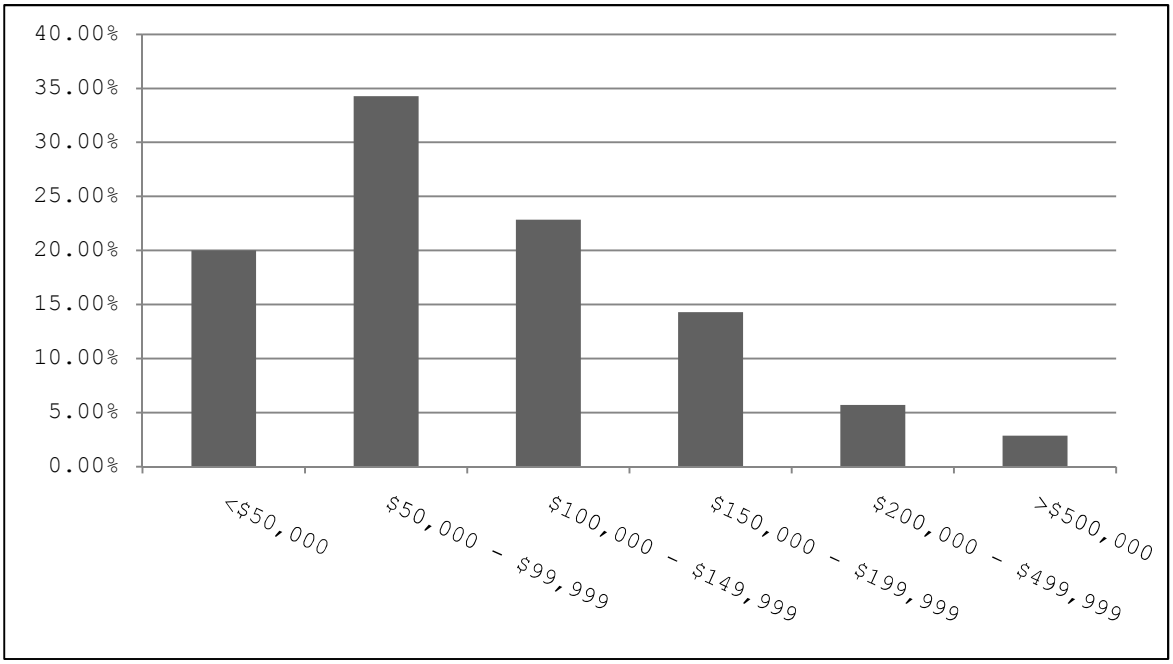


Figure 3. Net Household Income of Respondents

Appendix B: Survey Questionnaires

2009 Switchgrass Worksheet

Researchers at the University of Tennessee and Tennessee State University request your help in identifying challenges, benefits and general factors affecting the ability to continue growing switchgrass as a dedicated energy crop. The survey is part of a project entitled "**Will Small and Mid-Sized Farmers Benefit from the Cellulosic Energy Industrial Complex?**" This project is designed to maximize the participation of small and mid-sized farmers in the renewable energy market through enhancing their position as producers of biomass for the emerging cellulosic energy industry. As agricultural economists, we want to use the results of this survey to benefit farmers. Identifying farmers' limitations to continue production of switchgrass as a dedicated energy crop is essential for designing effective policy targets that incorporate farmers' perceptions and experience.

We understand there is uncertainty about the future market for switchgrass (e.g., conditions of contract, potential demand, etc); therefore, some sections might be answered based on your experience while others might be answered based on your feelings and expectations. This survey should take only about 20 minutes to complete. Please return the completed survey in the enclosed self-addressed envelope.

We want to assure you that your responses will be anonymous. Answering this survey is voluntary and your response serves as an informed consent to participate in the study. Your responses will not be published or communicated in any way that could possibly indentify you with them. Also, we assure you that after the survey is completed we will not be able to associate your name with your response.

Thanks in advance for your participation in this important survey. If you have questions about this survey please contact project researchers Dr. Margarita Velandia or Jessica Fox, Agricultural Economics, The University of Tennessee, at (865) 974-7231.

Instructions for Survey

Many questions in this survey make use of rating scales from 1 to 7; you are to circle the number that best describes your opinion. For example, if you were asked to rate the following question on such a scale from 1 to 7, the 7 places should be interpreted as follows:

> Continuing the production of switchgrass as a dedicated energy crop will improve my average profits:

unlikely: ___ 1___:____2___:___3___:___4____:____5____: ___6_____:___7___ likely
extremely slightly neither slightly extremely

For example, if you think continuing the production of switchgrass is *slightly likely* to improve your average profits, you would circle the 5 as follows:

unlikely: ___ 1___:____2___:___3___:___4____:____(5)____: ___6_____:___7___ likely
extremely slightly neither slightly extremely

The following are statements followed by rankings. Each ranking will be paired with a different scenario such as: likely and unlikely, rarely and frequently, or important and not important. Please answer each of the following questions by circling the number that best describes your opinion. Some of the questions may appear to be similar, but they do address somewhat different issues. Please read each question carefully.

In making your ratings, please remember the following points:
* Be sure to rate all items – do not omit any.
* Never circle more than one number on a single scale.

We ask that you express your opinion about some statements that we present below based on your experience with switchgrass and your expectations about the future development of a switchgrass market.

Expectations and beliefs about the switchgrass market

1. The development of a switchgrass market in the next 5 years is:
   unlikely: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ likely
2. The development of a switchgrass market in the next 10 years is:
   unlikely: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ likely
3. The development of a switchgrass market in the next 15 years is:
   unlikely: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ likely
4. Having a contract for me to establish a dedicated energy crop is:

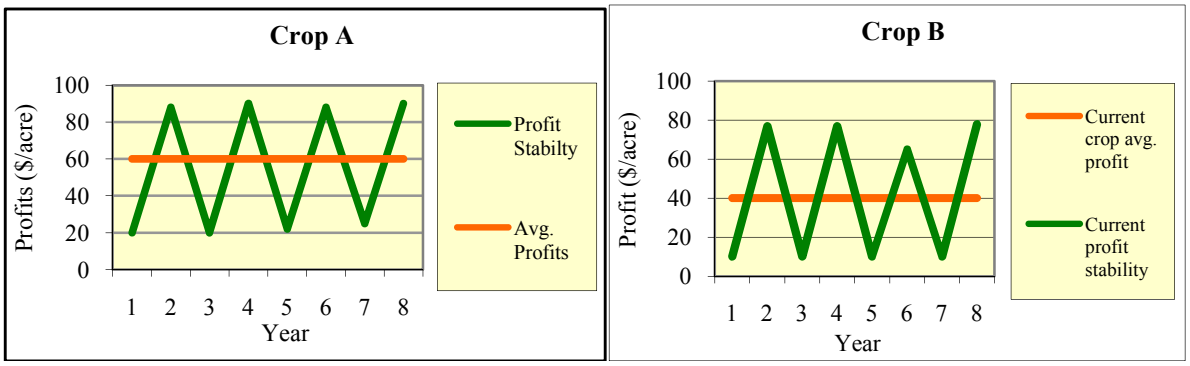
not important: ___1__:___2__:___3__:___4__:___5__: __6__:__7_ very important

5. What factors might affect the development of this market?_____

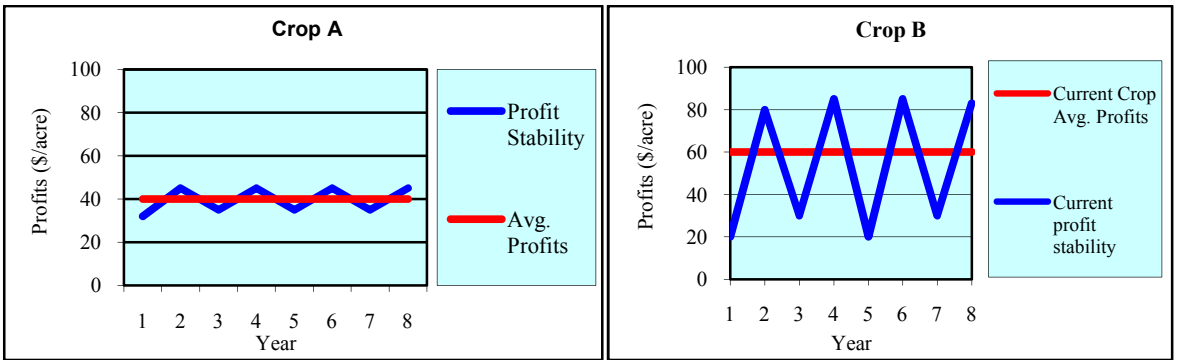
Behavioral Beliefs:

The following graphs are designed to exemplify the concepts of average and stable profits. These graphs and numbers have no relation to switchgrass or any other crop.

- **Case 1** (higher average profits same stability) – Production of crop A will improve farmers' average profits. On average, profits over a time horizon will be higher for crop A as compared with average profits for crop B. This choice however will not change the variability of weather and price conditions as in other crops.



- **Case 2** (lower average profits higher stability) – Production of crop A is reducing average profits and increasing the stability of those profits when compare with crop B.



6. Continuing the production of switchgrass will improve my average profits, and will also increase the stability of those profits:

unlikely :___1__:___2__:___3__:___4__:___5__:__6__:__7 likely

7. Continuing the production of switchgrass will improve my average profits, but will decrease the stability of those profits:
   unlikely :___1__:___2__:___3__:___4__:___5__:__6__:__7 likely
8. Continuing the production of switchgrass will stabilize my profits, but will not increase my average profits:
   unlikely :___1__:___2__:___3__:___4__:___5__:__6:__ 7 likely
9. Continuing the production of switchgrass as a dedicated energy crop will allow me to allocate equipment and time resources more efficiently during the off season:
   unlikely :___1__:___2__:___3__:___4__:___5__: __6__:__7 likely
10. Continuing the production of switchgrass as a dedicated energy crop will allow me to diversify my farm:
    unlikely :___1__:___2__:___3__:___4__:___5__: __6__:__7 likely
11. What other outcomes do you believe will result from your decision to continue growing switchgrass?

    _____

    _____

    _____

    _____

    _____

Outcome Evaluations:

12. For me, the ability to use equipment and time resources during the off season is important to improve the economic situation of my farm is:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
13. For me, to diversify my farm is:
    not important :___1__:___2__:___3__:___4__:___5__: __6__:__7 very important
14. For me, to increase my average profits even if that represents lower stability in those profits is:
    not important :___1__:___2__:___3__:___4__:___5__: __6__:__7 very important
15. For me, to stabilize profits even if it does not represent higher average profits is:
    not important :___1__:___2__:___3__:___4__:___5__: __6__:__7 very important

16. For me, to stabilize and increase my profits is:

    not important :___1__:___2__:___3__:___4__:___5__: __6__:__7 very important

Intention:

17. Given my current experience with switchgrass production and my expectations about the development of a market for switchgrass, I intend to continue growing switchgrass on my farm once my contract expires:

    unlikely :___1__:___2__:___3__:___4__:___5__:__6__:__7 likely

Expectations and beliefs about the switchgrass market:

18. List the factors that affect your intentions to continue growing switchgrass? _____

    _____

    _____

19. Do you expect the terms of your switchgrass contract to change in the future? Check one of the following : Yes _____ No_____

20. List below the ways you think the terms of your switchgrass contract will change?

    _____

    _____

21. List below the changes in your switchgrass contract that will dramatically affect your intentions to continue growing switchgrass?

    _____

    _____

Motivation to Comply:

22. The opinions of my family influences my crop production decisions:

    not all :___1__:___2__:___3__:___4__:___5__: __6__:__7 very much

23. The experience/opinions of other farmers about growing a new crop influence my production decisions:

    not all :___1__:___2__:___3__:___4__:___5__: __6__:__7 very much

24. My Extension agent's opinions about my production decisions influence my crop production decisions:

    not all :___1__:___2__:___3__:___4__:___5__: __6__:__7 very much

25. The UT Extension Switchgrass Specialist's opinions about my production decisions influence my crop production decisions:

    not all :___1__:___2__:___3__:___4__:___5__: __6__:__7 very much

26. What I hear in the media (TV, radio, internet, news paper, magazines, etc.) influences my switchgrass production decisions:

    not all: ___1__:___2__:___3__:___4__:___5__: __6__:__7 very much

Perceived Control Beliefs:

27. What percentage of your time, working on your farm, do you spend with equipment break downs associated with only switchgrass production in comparison to other crops in the past?

    - 0% - 13%
    - 14% - 27%
    - 28% - 41%
    - 42% - 55%
    - 56% - 69%
    - 70% - 83%
    - 84% - 100%

28. What percentage of your total time do you spend in non-farming activities?

    - 0% - 13%
    - 14% - 27%
    - 28% - 41%
    - 42% - 55%
    - 56% - 69%
    - 70% - 83%
    - 84% - 100%

29. What percentage of your time do you spend with crops and/or livestock other than switchgrass?

    - 0% - 13%
    - 14% - 27%
    - 28% - 41%
    - 42% - 55%
    - 56% - 69%
    - 70% - 83%
    - 84% - 100%

30. How often do you keep records for the crops and/or livestock you produce?

    rarely :___1__:___2__:___3__:___4__:___5__: __6__:__7 frequently

31. After the switchgrass crop is established, how often do you observe weed problems associated with switchgrass on your farm?

    rarely :___1__:___2__:___3__:___4__:___5__: __6__:__7 frequently

32. The level of erosion on my farm is:

    no erosion :___1__:___2__:___3__:___4__:___5__: __6__:__7 high level of erosion

33. Given the current conditions on my farm, I am capable of increasing switchgrass production by:

    - 0% - 13%
    - 14% - 27%
    - 28% - 41%
    - 42% - 55%
    - 56% - 69%
    - 70% - 83%
    - 84% - 100%

34. What are your most important challenges in producing switchgrass?

    _____

    _____

    _____

Power of Control Factors:

35. If equipment break downs associated with switchgrass production place additional unanticipated demands on my time, it will be difficult for me to continue producing switchgrass as a dedicated energy crop:

    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

36. If other non – farming employment places additional unanticipated demands on my time, it will be difficult for me to continue producing switchgrass as a dedicated energy crop:

    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

37. If I do not change my current distribution of time among all the other crops on my farm, it will be difficult to continue producing switchgrass as a dedicated energy crop:

    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

38. If I do not keep records of my operation, it will be difficult for me to continue producing switchgrass as a dedicated energy crop:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
39. If weed problems affect switchgrass after the crop is established, it will be difficult for me to continue producing switchgrass as a dedicated energy crop:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
40. If I could maintain soil on highly erodible areas in my farm by producing switchgrass, I would continue producing switchgrass:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
41. I can easily handle the time and resources necessary to increase switchgrass production on my farm:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

Normative Beliefs:

42. My family thinks that I should continue diversifying my farm with a dedicated energy crop:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
43. Other farmers in my area think that diversifying my farm with a dedicated energy crop is:
    not beneficial at all:___1__:___2__:___3__:___4__:___5__: __6__:__7 very beneficial
44. My County Extension Agent thinks that I should continue diversifying my farm with a dedicated energy crop:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
45. The UT Extension Switchgrass Specialists think that I should continue diversifying my farm with a dedicated energy crop:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
46. I have seen in the media (TV, radio, internet, paper, magazines, etc.) that farmers growing energy crops will help to alleviate the energy crisis (oil prices) in the U.S.:
    strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree
47. Who else (not mentioned above) usually affects your production decisions on the farm?
    _____

Trust in institutions (beliefs):

48. Government investment in clean energy programs to help farmers will determine the success of the switchgrass industry:

strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

49. Once Genera Energy and other potential companies start negotiating directly with farmers for contracts, these companies will provide the same level of service we are now receiving from UT Extension:

strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

Trust in institutions (outcomes):

50. Government support of clean energy programs is important for me to continue producing switchgrass:

strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

51. Having Genera Energy and other potential companies provide me with the same support as UT Extension is important for me to continue producing switchgrass:

strongly disagree :___1__:___2__:___3__:___4__:___5__: __6__:__7 strongly agree

About You and Your Household:

52. In what year were you born? (Fill in the blank) _____

53. Number of years farming? (Fill in the blank) _____

54. Number of years producing switchgrass? (Fill in the blank) _____

55. Which of the following describes the highest level of education you obtained? (Select one answer)

- o Some high school
- o High school Graduate or equivalent
- o Some college experience
- o Associate degree or Vocational school or equivalent
- o Bachelors degree
- o Graduate degree

56. About what percentage of your 2008 taxable household income was from farming? (Fill in the blank) _____%

57. Check the category that best reflects your taxable household income from both farm and non-farm sources in 2008: (Select one answer)

- o Under $50,000
- o $50,000 - $99,999
- o $100,000 - $149,999
- o $150,000 - $199,999
- o $200,000 - $499,999
- o $500,000 or more

58. How many persons reside in your household, including yourself? (Select one answer)
- o 1
- o 2
- o 3
- o 4
- o 5 or more

59. Have you ever grown a non-traditional crop before?
- o Yes
- o No

60. If yes, were you successful in producing that non-traditional crop?
- o Yes
- o No

61. Are you now growing a dedicated energy crop other than switchgrass?
- o Yes
- o No

62. Have you ever attended an educational meeting about switchgrass?
- o Yes
- o No

63. Have you ever planted a crop solely for wildlife habitat?
- o Yes
- o No

64. How many acres of the following do you produce: (Select one answer)
- o Corn _____ ac
- o Soybean _____ ac
- o Pasture/Hay _____ ac
- o Tobacco _____ ac
- o Wheat _____ ac
- o Switchgrass _____ ac
- o Other _____ ac

Effort Survey:

The following are statements followed by rankings. Each ranking will be paired with the scenario strongly disagree and strongly agree. Please answer each of the following questions by circling the number that best describes your opinion. Please read each question carefully.

We ask that you express your opinion about the statements that we present below based on your experience with each switchgrass producer.

1. The farmer is willing to listen/learn from the switchgrass specialists.

   Strongly disagree: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ strongly agree

2. The farmer shows enthusiasm when learning about switchgrass production as a dedicated energy crop.

   Strongly disagree: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ strongly agree

3. The farmer plans and follows appropriate production deadlines.

   Strongly disagree: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ strongly agree

4. The farmer keeps track of details that would guarantee a successful switchgrass crop (i.e. producing an initial strong stand, managing weeds, etc.).

   Strongly disagree: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ strongly agree

5. The farmer acts intuitively when identifying factors that may put the success of the switchgrass crop at risk (i.e. spraying when a weed problem is identified).

   Strongly disagree: ___1__:___2__:___3__:___4__:___5__:__6__:__7_ strongly agree

Vita

Jessica Elise Fox was born in Murfreesboro, Tennessee, on June 4, 1986 to Lynne and Bobby Fox. She graduated from Cascade High School in Bell Buckle, Tennessee in 2004. She attended the University of Tennessee, Knoxville and received a B. M. in Agricultural Economics and Business in 2008 and a M. S. in Agricultural Economics in 2010.