Farmers' Willingness to Grow Switchgrass as a Cellulosic Bioenergy Crop: A Stated Choice Approach

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Introduction

Government mandates for increases in cellulosic ethanol under the Energy Independence and Security Act of 2007 are set to take effect in 2015 (U.S. Congress 2007). These mandates require the use of "advanced" sources for biofuel production including agricultural residues, woody resources, municipal waste, algae, or other sources to produce 21 of 36 billion gallons of biofuel by 2022 (U.S. Congress 2007). However, the viability of the cellulosic biofuel industry is still unknown in areas such as biomass production, storage, and transportation.

Much research has assessed the technical feasibility to produce biofuels from lignocellulosic materials on agricultural land in North America (De la Torre Ugarta, English and Jensen 2007, R. L. Graham 1994, Graham, et al. 2007, W.G. Heid 1984, Gallagher, et al. 2003, Perlack, et al. 2005, Walsh, et al. 2003, Nelson, et al. 2010). Research has looked at the viability of growing bioenergy crops from the perspective of land availability and farmer profitability. Land use change is an important consideration for energy crops' production. Moving from production of traditional crops to energy crops will alter the traditional crop mix to a degree because farmers will grow less corn, soybeans, wheat, sorghum, cotton, or rice, and more biomass crops. Land previously enrolled in conservation programs may also be moved into energy-crop production to help meet renewable fuel requirements and ensure farmer profits.

However, technical feasibility studies do not provide "necessary economic and institutional conditions" that a cellulosic biofuel industry requires (Rajagopal, et al. 2007). While farmers' ability to produce adequate quantities of biomass for bioenergy throughout the Great Plains is unquestionable, their willingness to do so under different contractual, pricing, storage,

and transportation contexts is unknown, especially with respect to perennial biomass crops such as switchgrass and miscanthus.

The lack of an established market adds a great deal to the uncertainty farmers face during development of this nascent industry. Farmers' willingness to adopt new technologies or practices often depends on their knowledge of the technology or practice and their skills at operating or implementing the practice (Pannell, et al. 2006). However, farmers' willingness to grow new crops likely depends not only on knowledge and skill, but also on land tenure, demographic, and social characteristics. Some research has attempted to determine how these factors affect farmers' adoption characteristics with respect to biofuel crops (Anand, et al. 2008, Bransby 1998, Hipple and Duffy 2002, Jensen, et al. 2007, Kelsey and Franke 2009). Farmers will grow bioenergy crops if the returns to the crop outweigh production costs, including opportunity costs (Rajagopal, et al. 2007). However, the production of dedicated energy crops combined with decreases in traditional crop, forage, and livestock production will cause prices for these displaced commodities to increase in the long term and competition among dedicated energy crops will increase (Dicks, et al. 2009, Walsh, et al. 2003).

Well-established markets exist for most commodities farmers produce, which decreases uncertainty and risk (Epplin, et al. 2007). But because biomass markets are not yet established, it is likely farmers will grow bioenergy crops under contractual relationships that establish pricing, timeframe, harvest timing, storage requirements, acreage requirements, yield requirements, and other arrangements between farmers and biorefineries (Altman, Boessen and Sanders 2007, Epplin, et al. 2007, Glassner, Hettenhaus and Schechinger 1998, Larson, English and Lambert 2007, Stricker, et al. 2000, Wilhelm, et al. 2004). Processing plants will value the product as an input, and base its willingness to pay on the price it can receive for output, while farmers'

decisions to grow biomass will depend on profit potential, machinery requirements, markets, government policy, and other subjective criteria specific to each operator such as covering costs (Paine, et al. 1996, Mapemba and Epplin 2004). The disparity between biorefineries and farmers' views about the value of the biomass necessitates careful contract design.

One of the popular options for a bioenergy crop in the Great Plains is switchgrass because switchgrass planting decreases soil erosion over cultivation, uses one-half as much nitrogen fertilizer as corn, requires one herbicide application in the establishment year, and is both more drought and flood tolerant than traditional crops (McLaughlin and Walsh 1998). However, switchgrass production is less likely to occur on highly productive land and more likely on marginal land or land already enrolled in conservation programs such as CRP to increase revenue (Paine, et al. 1996).

This study seeks to determine farmers' willingness to grow switchgrass as a bioenergy crop while helping facilitate contract design and biomass price establishment. Few (if any) studies have elicited farmers' opinions about bioenergy crops and assessed their willingness to produce these crops instead of traditional crops. With farm profitability at near record highs, it is even more important to assess whether farmers want to enter into bioenergy crop enterprises or continue with their established practices. A stated choice survey was developed to elicit Kansas farmers' willingness to grow switchgrass as a bioenergy crop under alternative contractual, pricing, and harvesting arrangements. The stated choice format allows farmers to choose among alternatives following Louviere, Rose, and Greene (2005) and survey results can be analyzed using a conditional logistic regression model with error components (Bhat 1998, Greene, Econometric Analysis 2008).

Switchgrass as a Bioenergy Crop

The viability of producing switchgrass as a bioenergy feedstock in the Great Plains has been the topic of much research (Perlack, et al. 2005, Mapemba and Epplin 2004, Epplin, et al. 2007, Bangsund, DeVuyst and Leistritz 2008). Switchgrass is a perennial grass, native to much of the Great Plains, and has been touted as the best potential energy crop based on research conducted across 31 locations over several years in the late 1980s and early 1990s (Wright 2007). It requires low maintenance after its establishment phase, is noninvasive, and is suited to many soil types in different parts of the country, including marginal lands not necessarily valuable for high-value crops such as corn or soybeans (Wright 2007). Harvesting, transporting, and storing switchgrass is similar to well-established hay production practices (Wright 2007), although long-term biomass storage may reduce biofuel yields (Rigdon, et al. 2011). In addition, planting switchgrass (or other perennial crop) reduces erosion and increases soil carbon content (Wright 2007, McLaughlin, de la Torre Ugarte, et al. 2002).

Production costs for switchgrass in the initial planting phase are high relative to other crops, in part due to the long-term nature of the crop. Seed costs range from $150 to $200 per acre and the first two years' of production are reduced until the crop is established. Switchgrass is planted in the spring and weeds are controlled via spraying, mowing, or grazing (Ohlenbusch 1997). After the crop is well established, 90 to 120 pounds of nitrogen fertilizer can be applied to increase production, followed by phosphorus and potassium if soil testing warrants (Ohlenbusch 1997, Teel, Barnhart and Miller 2003). Fertilizer costs will vary depending on soil requirements and location.

On a national level, switchgrass has the potential to produce as much as 8.4 tons per acre annually (McLaughlin, de la Torre Ugarte, et al. 2002) with local yields reaching over 15 tons

per acre depending on rainfall, length of growing season, soil types, etc. In addition, nitrogen use is lower and returns are higher for switchgrass than other types of grasses with potential use as biofuel feedstock (Aravindhakshan, Epplin and Taliaferro 2011).

Figure 1 shows the potential to produce switchgrass in the United States east of the Rocky Mountains. The estimates occur under a price to the farmer of $44 per megagram ($19.96 per short ton) at the farm gate that would entice farmers to plant switchgrass rather than traditional crops. Obviously, high commodity prices in recent years may preclude farmers' planting of switchgrass in favor of traditional crops.

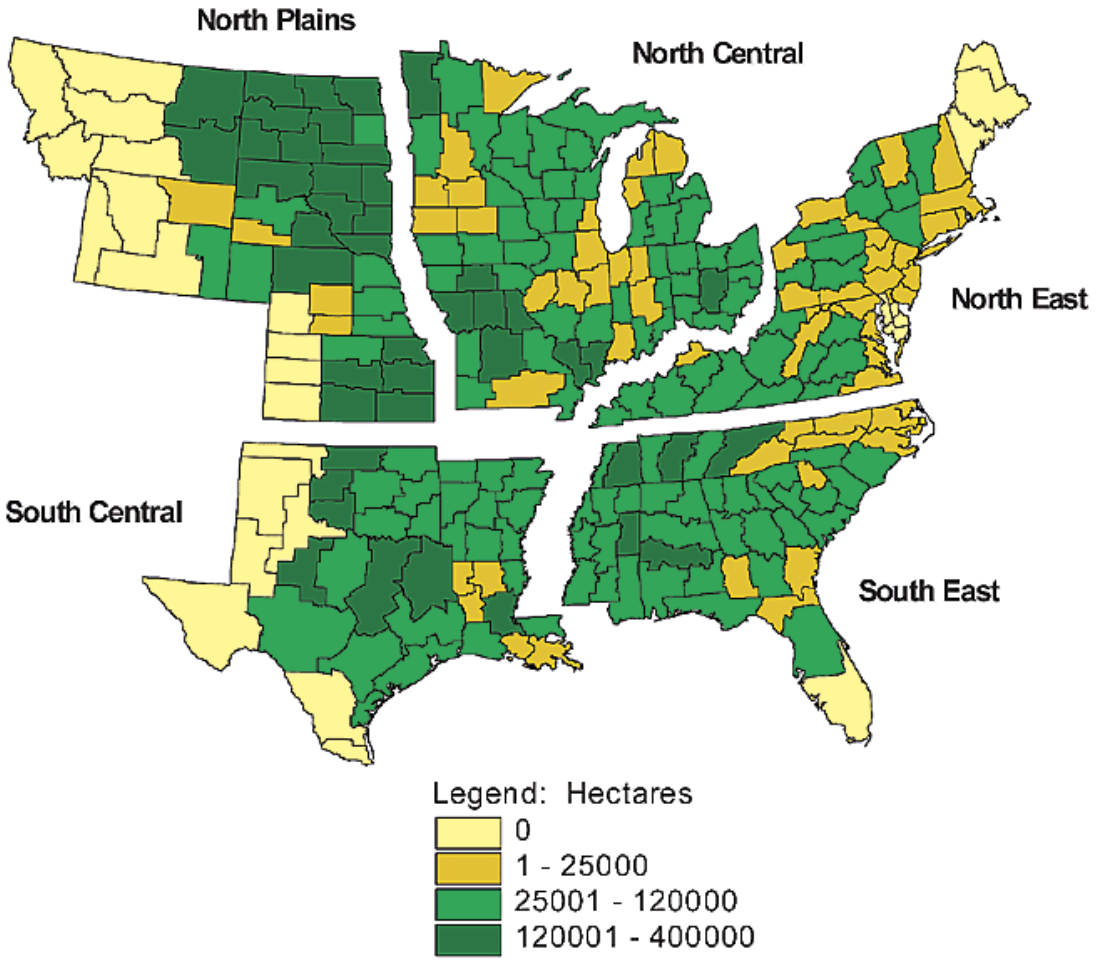

Figure 1. Potential switchgrass production areas in the United States based on distribution of land that converts to switchgrass production from traditional agricultural production at a farm gate price of $44/Mg (McLaughlin, de la Torre Ugarte, et al. 2002).

Survey Methods and Data

A stated choice survey was administered from November 2010 to February 2011 in three areas of Kansas by Kansas State University and the USDA, National Agricultural Statistics Service (NASS). The survey assessed farmers' willingness to produce cellulosic biomass in the form of corn stover, sweet sorghum, and switchgrass for bioenergy production under different contractual arrangements. A total of 485 farmers were contacted in northeastern, south central, and western Kansas to participate in the survey. These areas of Kansas were selected based on the number of farms growing corn and/or sorghum and the mix of irrigated and dryland production. A random sample of approximately 160 farms over 260 acres in size and $50,000 in gross farm sales were selected from the USDA-NASS farmer list for the three areas of the state examined. Farmers already participating in USDA-NASS enumerated surveys (e.g. ARMS) were removed from the sample and replaced with another randomly drawn name. Prior to the survey entering the field, the stated choice component was field tested with focus groups at an annual extension conference hosted by the Department of Agricultural Economics at Kansas State University and the entire survey was tested using face-to-face interviews with farmers in the targeted study areas.

Potential participants received a four-page flier via mail asking for their participation in the survey and providing information about cellulosic biofuel feedstock production on-farm one week prior to being contacted by USDA-NASS enumerators. USDA-NASS enumerators then scheduled one-hour interviews with the farmers to complete the survey and stated choice experiments. Interviews, on average took 57 minutes to complete. Upon completion of the survey and receipt at the USDA-NASS office in Topeka, farmers were compensated for their time with a $15 gift card. Of the 485 farmers contacted, 290 completed the survey and 38 were

out-of-business, did not farm, or could not be located. Thus, the survey response rate was (290/(485-38)) = 0.65 or 65 percent. Of the 290 respondents who completed the stated choice experiment for sweet sorghum, six surveys were incomplete due to lack of responses on the switchgrass experiment or refusal to answer demographic questions, leaving 284 usable surveys for this study.

After answering a number of questions about their farming operation, respondents were asked about their willingness to produce switchgrass as a cellulosic biofuel feedstock under contract. After this section of the survey, respondents were asked about biofuel feedstock production preferences and perceptions; conservation on-farm and perceptions; risk management practices and perceptions; crop marketing practices; and demographics.

Farmer demographics taken from the 2007 U.S. Census of Agriculture (National Agricultural Statistics Service 2009) were used to determine whether the survey respondents are representative of Kansas farmers. Table 1 compares some of the demographics reported by farmers in the survey to statewide numbers as recorded in the 2007 Census of Ag. The percentage of farmers who are white is the same for both the census and survey. A slightly lower average age is reasonable given our survey sampled larger farms that are likely to be operated by younger farmers. Average farm size and amount of rented land are considerably larger for our survey since we chose farms over 260 acres in our sample, thus eliminating many small, or hobby farms. More of the survey respondents are male than in the Census figures, but the size of the farms may explain this since larger farms are more likely to be operated by males. Average value of agricultural products found in the survey includes the value reported by the Census figures. The survey asked respondents to choose a range in which their agricultural value of sales fell, and the most oft chosen range matches Census of Ag figures.

Table 1. Comparison of Kansas farmer demographics to survey respondents.

	2007 Census of Agriculture	Survey
Percent white	98.9%	98.9%
Age	57.7 years	55.9 years
Percent male principal operators	87.9%	95.9%
Average size of farm	707 acres	2147 acres
Average amount of rented land in farm	863 acres	1388 acres
Average market value of agricultural products	$219,944	$200,000 to $399,999

Stated Choice Experiment Set-Up

The stated choice experiment was designed to assess farmers' willingness to produce switchgrass for biofuel under contract with biorefineries or other biomass processors following Louviere, Hensher, and Swait (2000) and Roe, Sporleder, and Belleville (2004). The survey provided a brief explanation of switchgrass production and explained the contract attributes before requiring a response to the stated choice experiment, as shown in Figure 2. Survey respondents were asked to consider five independent choice scenarios with options to choose between two contracts or an "opt out" option, as shown in Figure **3**. Contract options were unlabelled and had five attributes: (1) Net returns above CRP or Hay Production, (2) Contract Length, (3) Biorefinery Harvest Option, (4) Insurance Availability, and (5) Seed Cost-Share Provision.

SECTION 2A ***PERENNIAL BIOENERGY CROP OPTION: SWITCHGRASS***

This section will ask about your willingness to supply switchgrass, a perennial bioenergy crop, to a biorefinery or intermediate processor (e.g. cooperative) through different contractual agreements. You will be asked to consider 5 scenarios. Each scenario contains three options: two contract options and one for "do not adopt." The final option provides the option to "opt out" if the contracts presented are not favorable to you. Each contract will have different features, which include net returns per acre, contract length, a harvest option, an insurance availability option, and a cost-share provision option.

Switchgrass is a perennial crop that can be grown in place of other annual crops, on hay land, or less productive lands (e.g. CRP land). Harvesting of switchgrass involves cutting, raking and then baling the stalks. Switchgrass has a two-year establishment period with no harvest in the first year, a reduced yield in year two, finally reaching full yield potential in year three. Replanting occurs about every 10 years. Expected biomass yields for switchgrass range from 1 to 8 dry tons per acre, but yields will vary depending on climatic conditions and geography. In the future, biomass yields are expected to increase with improvements in plant breeding and harvest technology. Biomass harvesting can be done by the farmer (with his/her own equipment or by hiring a custom operator) or by the biorefinery. Harvesting would take place in the late fall or could occur during the winter. The annual average cost of production for a switchgrass enterprise ranges from $44 to $142 per acre. In the following scenarios, the biorefinery will be responsible for long-term storage of biomass; a minimum acreage contract will be negotiated between the bio-refinery and farmer; and the contract will include an "Act of God" clause.

Each scenario presented will present different contractual options with the following features:

Contract Feature	Description
Net Returns (*for all features of the contract except the seed/establishment costs*)	Represents the expected ***percentage*** gain under the contract ***above*** net returns associated with hay production and/or CRP rental payments on your operation. As a reference point, on average, returns from hay production or income from land in CRP are expected to be around $40 per acre in Kansas. For example, if your CRP rental rate is $40/acre, a 10% return above $40 per acre will be $44/acre. This amount is received after all expenses, including harvest and insurance are paid, but **does not** include the seed/establishment cost-share payment.
Contract Length	Represents the time commitment in consecutive years of the contractual agreement.
Biorefinery Harvest	"Yes" indicates the bio-refinery will harvest the biomass at their expense, and "No" means the farmer is responsible for harvest (including cutting, raking, baling and transportation to the bio-refinery). Harvest charges are included in the percentage net return. That is, the charges are considered paid regardless of who harvests the biomass.
Insurance Availability	"Yes" indicates crop insurance is available, and "No" otherwise.
Seed/Establishment Cost-Share	Indicates a percentage of seed/establishment costs are covered or cost-shared by the biorefinery or processor during the first two years of production or after planting due to lower yields during the establishment period. Establishment costs can range from $150 to $200 per acre. This will be provided every time the crop is replanted. This cost-share is provided in addition to the net returns indicated above.

Figure 2. Example of explanation of switchgrass production and contract attribute descriptions.

Switchgrass Scenarios – For each scenario evaluate the contractual options and please rank the contract options in the order that you would prefer them with 1 = first choice, 2 = second choice, and 3 = third choice.

CONSISDER EACH SCENARIO INDEPENDENTLY .

Scenario 1:

		Contract A	**Contract B**	**Option C**
Contract Features	**Net Return Above Hay Production/CRP Rental Rates (Base: $40/ac)**	35% Higher/year	5% Higher/year	Do Not Adopt
	Contract Length	16 Years	7 Years	
	Biorefinery Harvest	Yes	No	
	Insurance Available	No	Yes	
	Seed/Establishment Cost-Share	35%	70%	
	Your Ranking (1-3)	2069 ☐	2070 ☐	2071 ☐

Figure 3. Example of stated choice question format for the switchgrass choice scenario.

It is assumed that switchgrass will only be planted on marginal land that is not renewed in CRP or that is in current hay production. Therefore, net returns above hay or CRP payments had three levels: 5%, 20%, and 35%. Using the percentage net returns above those earned from typical crop production practices, a market price for biomass can be determined based on current market and production conditions, without putting a precise monetary value on the biomass. In addition, using the percentage net return above corn production will allow prices to "float" to levels that will entice farmers to adopt these bioenergy crops. This biomass valuation method is useful because many farmers are unwilling to make a decision to grow biomass without knowing production costs and actual dollar returns. Policy makers and the biofuel industry will benefit from the survey results because they will know whether farmers are willing to supply biomass, while realizing prices required for farmers to adopt. The method benefits biorefineries by helping them determine prices they can afford to pay for biomass by knowing how much farmers require

to make it a worthwhile enterprise. A base value of $40 per acre was assumed based on the average CRP rental rate across Kansas. The attribute is recoded from a percentage to a dollar amount for analysis purposes.

Contract length has two levels: 7 years and 16 years. Since switchgrass is planted approximately once every ten years, a producer may wish to enter into a contract length of at least seven years. If they choose to continue producing switchgrass, it is likely they would enter into a contract for 16 (or more) years. However, 7- and 16-year contracts allow a producer to discontinue switchgrass production if they chose to transition their land back into regular crop or hay production, or to grow CRP.

To add flexibility to the contract options, an effects coded biorefinery harvest option is added as a binary choice that offers the option, but does not require the farmer to allow a biorefinery on their land to harvest the biomass. Net returns includes the cost of biorefinery harvest. Insurance availability is another effects coded binary attribute that indicates whether a crop-insurance type instrument is available for farmer purchase under the biomass contract. Effects coding helps capture the grand mean without confounding a base level mean that can occur when assigning dummy codes or usual binary coding (Hensher, Rose and Greene 2005). In addition, assigning a zero to the value would indicate the attribute is not included in the contract.

Finally, a seed-cost share attribute is included with three levels: 0%, 35%, and 70%. The high cost of establishing switchgrass may necessitate the biorefinery's sharing in seed costs. The three levels indicate a percentage of the seed cost the biorefinery would pay under each contract scenario.

The choice scenarios contain two generically labeled contracts with attributed levels assigned randomly and an option to "opt out." Following Louviere, Hensher, and Swait, (2000) a

$(2^3 \text{ x } 3^2)^3$ fractional factorial design was used to develop 90 random choice sets in order to identify all main effects and any potential interaction effects between attributes and levels. The choice sets were randomly assigned into 18 blocks (18 survey versions) so each respondent was presented with five choice scenarios (see Figure 3). Of the 290 answered surveys, between 12 and 20 of each survey version was completed.

Summary Statistics

The most popular first choice among respondents was "do not adopt" with 1047 of 1420 responses. This leaves only 373 choices, or 26.3%, where a contract (either A or B) would be adopted. This is expected with an enterprise such as switchgrass. A great deal of uncertainty surrounds switchgrass production with regard to yield, seed, production, and maintenance costs, and net returns. In addition, establishing the crop for ten years (or more) causes some hesitation due to uncertainty with regard to opportunity costs of not growing traditional crops. Finally, farmers are reluctant to enter into such long-term contractual arrangements. The results section includes a more in depth discussion of this topic. It is interesting to note, however, that when asked, "Considering you enter into a favorable contract with a biorefinery, would you produce [switchgrass] on your farm?", 69.8% responded they would grow switchgrass and initially commit an average of 101 acres.

Table 2 contains a description of the attributes and levels as well as summary statistics for the values of the attributes presented to farmers where the first choice was to adopt a contract (either A or B). Contract length is somewhat shorter when the first choice was to choose a contract, which is expected given that farmers desire shorter contracts. Net returns and seed cost share have higher means for the chosen contract options than in the entire sample, indicating farmers choose higher levels of these options when possible. The binary options, biomass harvest

and insurance availability, have means near zero, indicating an even number of each was offered as an option and chosen by farmers. In the northeast section of the state, 113 respondents chose to adopt a contract as their first choice. In the central part of the state, 139 chose to adopt, and in the west, 121 chose to adopt a contract as their first choice.

Table 2. Attribute descriptions and summary statistics of attributes and levels for each randomly assigned contract type for the entire sample versus those who chose a contract as their 1st choice.

			Entire Sample (*N* = 1420)		**1st Choice to Adopt (*N* = 373)**	
Attribute	**Attribute Description**	**Levels**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Net Returns Above Hay/CRP (%)	Represents the expected ***percentage*** gain under the contract ***above*** net returns associated with hay production and/or CRP rental payments on your operation.	5% 20% 35%	20.032	12.195	23.981	11.236
Contract Length (years)	Represents the time commitment in consecutive years of the contractual agreement.	7Years 16 Years	11.231	4.493	9.775	4.162
Biomass Harvest Option[a]	"Yes" indicates the bio-refinery will harvest the biomass at their expense, and "No" means the farmer is responsible for harvest (including cutting, raking, baling and transportation to the bio-refinery). Harvest charges are included in the percentage net return. That is, the charges are considered paid regardless of who harvests the biomass.	Yes = 1 No = -1	0.018	1.000	0.137	0.992
Insurance Availability[a]	"Yes" indicates crop insurance is available, and "No" otherwise.	Yes = 1 No = -1	-0.037	1.000	0.046	1.000
Seed Cost Share (%)	Indicates a percentage of seed/establishment costs are covered or cost-shared by the biorefinery or processor due to lower yields during the establishment period. This will be provided every time the crop is replanted. This cost-share is provided in addition to the net returns indicated above.	0% 35% 70%	33.829	28.541	40.161	27.574

[a] These binary attributes were effects coded.

Conceptual Model and Econometric Analysis

Following Roe, Sporleder, and Belleville (2004), assume producers maximize expected discounted utility when they choose to enter into a switchgrass contract instead of producing hay or traditional crops. Then, producer *j*'s expected discounted utility for contract *i* is:

$$V_{j,i} = V\left(\Delta R_i\left(H_i, I_i\right), C_i, S_i, E_{j,i}\right) + L_{ki} + \varepsilon_{j,i} \tag{1}$$

where ΔR_i is the net return above CRP or hay production over time, and includes the costs associated with earning those returns, H_i, the biomass harvest option, and I_i, biomass crop insurance availability. Other contract attributes include C_i, the contract length in years, S_i, the seed cost-share attribute, and $E_{j,i}$, a vector of error components or "alternative-specific random individual effects that account for choice situation invariant variation" (Greene 2007). This is due to the unobserved preference heterogeneity that occurs due to correlation across alternatives where $E_{j,i}$ has mean zero and variance equal to one (Greene 2007). The error components follow a tree structure distributed across the alternatives (Greene 2007). Due to variation in climate and growing conditions across Kansas, a fixed effects location parameter, L_{ki}, is added to account for farmers in the northeast, west, or central portions of the state. Finally, the error term, $\varepsilon_{j,i}$, represents the nonsystematic part of expected utility that is unobserved by the researcher and is distributed Type I extreme value (Louviere, Hensher and Swait 2000).

This study's primary interest is assessing direct impacts of contract attributes on farmers' willingness to accept a contract. Therefore, following Roe, Sporleder, and Belleville (2004), the focus becomes the reduced-form representation of expected utility. A main effects model with error components following Bhat (1998) and Greene (2007) for producer *j* and contract *i* is:

$$V_{j,i} = \beta_0 + \beta_1 \Delta R_i + \beta_2 C_i + \beta_3 H_i + \beta_4 I_i + \beta_5 S_i + \beta_6 L_{1i} + \beta_7 L_{2i} + \sum_j \theta_j E_{j,i} + \varepsilon_{j,i} \tag{2}$$

for j = A, B, or C where θ_j is the standard deviation of the error component, or random effect, $E_{j,ii}$. This model captures correlations among choice alternatives in the model, which allows for relaxing the IIA assumption found in traditional conditional logistic regressions (Greene 2007). Contract choices A and B represent the randomly assigned, unlabeled contract choices for each scenario, while Option C is the "opt out" option. As seen in Figure 3, Option C does not contain any attributes, so $\beta = 0$, and $V_{C,I} = \theta_C E_{C,I} + \varepsilon_{j,i}$. This allows the model to control for unobserved individual effects associated with "opting out." Utility functions for Contracts A and B contain error components for A and B, which allow the generic choices to capture correlation among any choices that arise.

Assuming farmers are profit maximizers, the sign for β_1 and β_5 is expected to be positive since higher net returns and lower-cost seed can both contribute to increased profit. Farmers likely prefer short-term contracts, so the sign of β_2 should be negative. The signs for β_3 and β_6 may be either positive or negative depending on farmers' views about biorefinery harvest being a cost-saving option, or if farmers are reluctant to allow custom operators on their property and location. The sign for β_4 is expected to be positive since farmers will likely prefer insurance availability as a tool to manage risk—especially on "experimental" crops.

While respondents ranked their choices, this paper only examines their first choice. Thus, equation (2) is modeled using a conditional logistic regression model with error components and the above stated restrictions following Greene (2007) and Hensher, et al. (2005). NLOGIT 4.0 (Greene, 2007) is used to estimate the model, using simulated maximum likelihood with 1000 Halton draws using the BFGS Quasi-Newton Algorithm. Predicted probabilities, estimated marginal effects, and farmers' willingness to pay for alternative contractual features are

calculated in a spreadsheet. Standard errors for all statistics using model results are calculated using the delta method following Greene (2003).

Results

Results show the willingness of farmers to grow switchgrass as a bioenergy feedstock. Table 3 contains the parameter estimates from estimating the error components model, as well as the error components of the random effects logit model. Error components take into consideration the weight of uncertainty that affects each respondent's decision, are unobservable, and are treated as random parameters containing individual-specific error term distributions (Hensher, Rose and Greene 2005). McFadden's Pseudo R^2 indicates data fit the model well.

Table 3. Coefficient estimates for the error components model. The model estimates a linear utility function and coefficients' signs indicate increased or decreased likelihood of adoption given contract attributes.

Variable	Coefficient	Standard Error	b/Std.Error	P-Value
Nonrandom parameters in utility functions				
Constant	-4.6800	0.5050	-9.268	0.0000
Net returns	0.1626	0.0178	9.142	0.0000
Contract length	-0.1662	0.0162	-10.273	0.0000
Harvest option	0.3409	0.0783	4.352	0.0000
Insurance avail.	0.2413	0.0874	2.761	0.0058
Cost share	0.0250	0.0029	8.706	0.0000
Northeast	-0.7726	0.5148	-1.501	0.1335
Central	1.2787	0.5524	2.315	0.0206
Standard deviations of latent random effects (error components)				
Contract A	0.6153	0.3426	1.796	0.0725
Contract B	0.0145	7.3793	0.002	0.9984
Option C	4.9405	0.5787	8.538	0.0000
Model Fit Statistics				
Restricted Log-Likelihood		-1560.029		
AIC		0.97446		
McFadden Pseudo R^2		0.5636		

Probability of Adoption

The probability of adoption follows the logit pdf,

$$P = e^{\beta' X} \Big/ (1 + 2e^{\beta' X}), \tag{3}$$

where P = probability of adopting a contract, and

$$\beta' X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 \tag{4}$$

The figures below show the probability of adoption at varying levels of net returns above hay production for different contract lengths with and without the insurance and seed cost-share options in the three sampled areas of Kansas. Results indicate that farmers are more likely to grow switchgrass under shorter contracts and they prefer an insurance option. For instance, Figure 4 shows that, in northeast Kansas at net returns of $35 per acre, a 7-year contract is about 6% more likely to be adopted if insurance is available than if it is not. For a 16-year contract, the difference is only about 4%. In addition, a 7-year contract without insurance is about 15% more likely to be adopted than a 16-year contract. Comparing Figure 4 and Figure 5 indicates that adding a 35% seed cost-share option increases the likelihood of adoption of a 7-year contract without insurance from 23.5% to 34%, and with insurance from 29.5% to 38%.

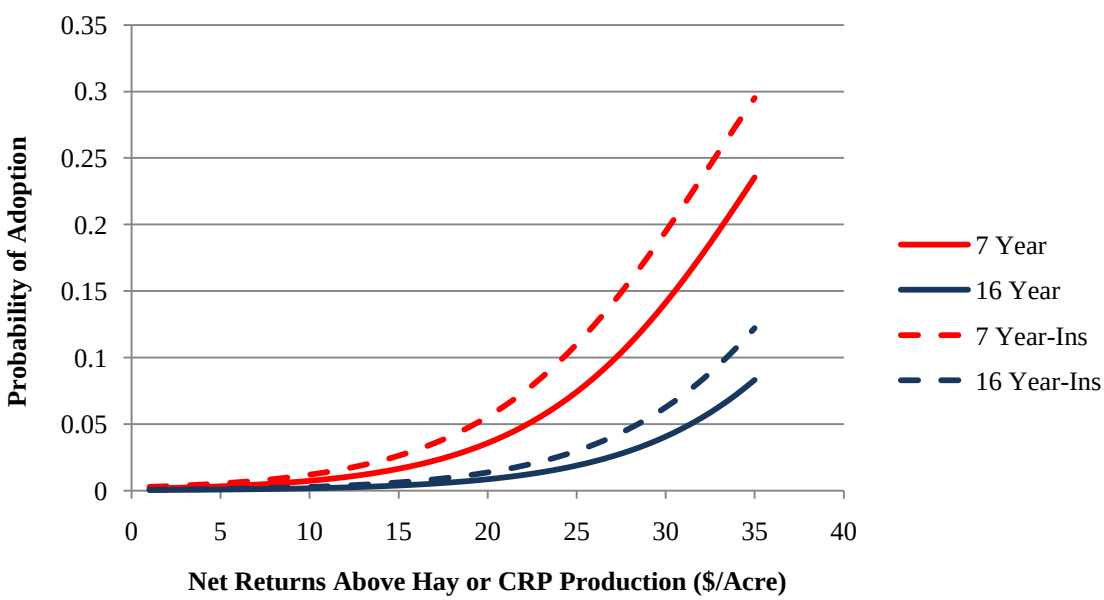

Figure 4. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; no cost share; northeast Kansas.

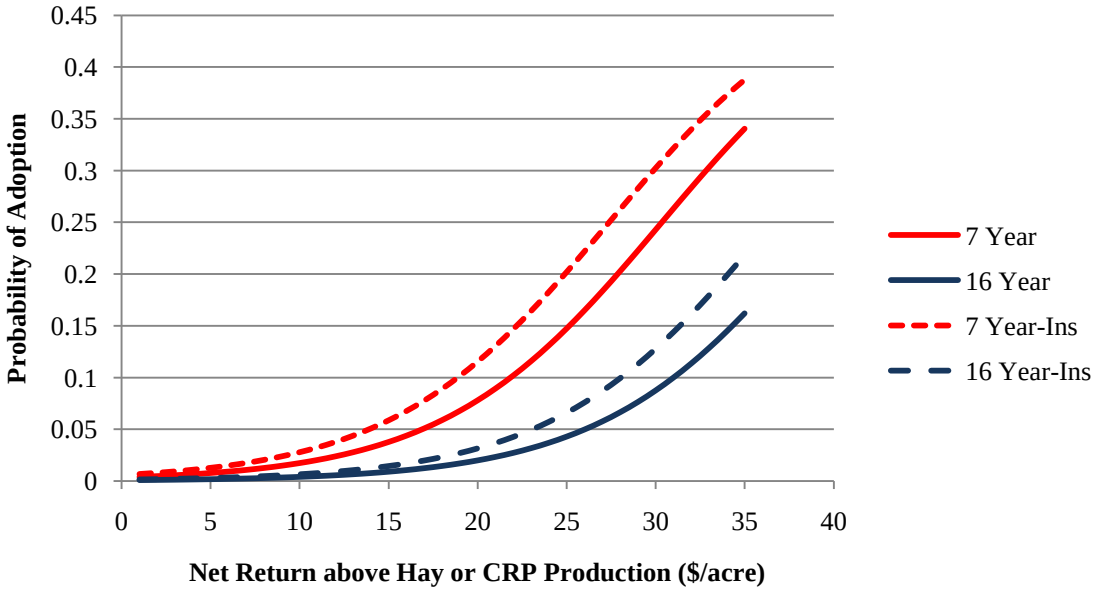

Figure 5. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; 35% cost share; northeast Kansas.

Central Kansas farmers are the most likely to adopt switchgrass under the contract scenarios. Under the 0% cost-share option in Figure 6, farmers have about a 44% probability of adopting a 7-year contract to grow switchgrass without insurance and a 46% probability with insurance. Likewise, they will adopt a 16-year contract with a probability of 30% without insurance and 36% with insurance. Other farm characteristics and demographic factors will likely account for this result and bears further study. When the 35% cost-share option is added to the contract options in Figure 7, farmers increase their likelihood of adopting a 7-year contract to 47% and 48% without and with insurance, respectively, and their likelihood of adopting a 16-year contract increases to 39% and 43% without and with insurance, respectively.

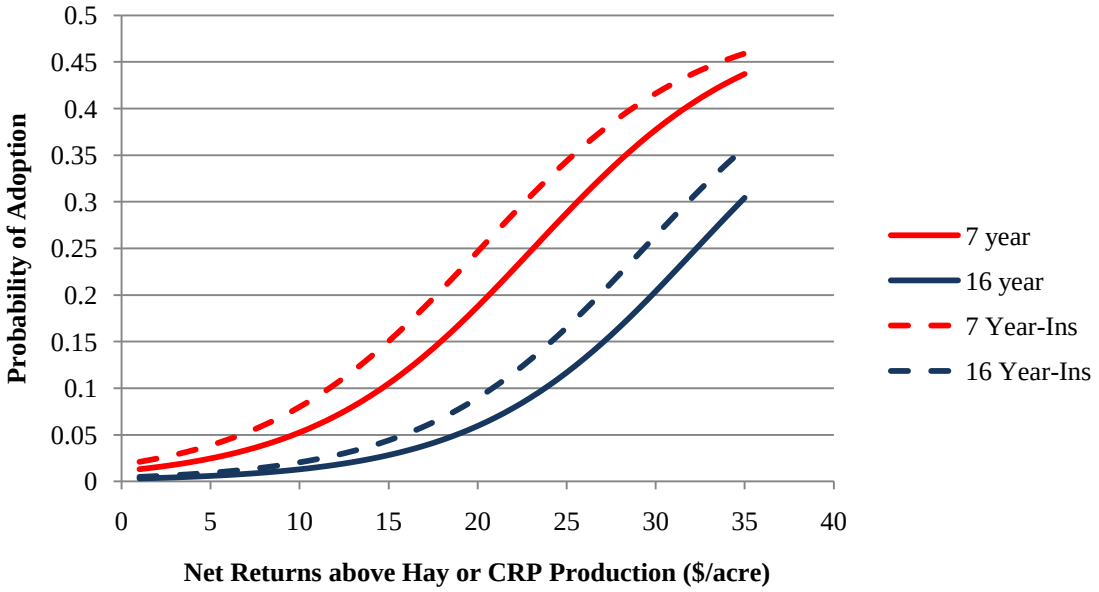

Figure 6. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; no cost share; central Kansas.

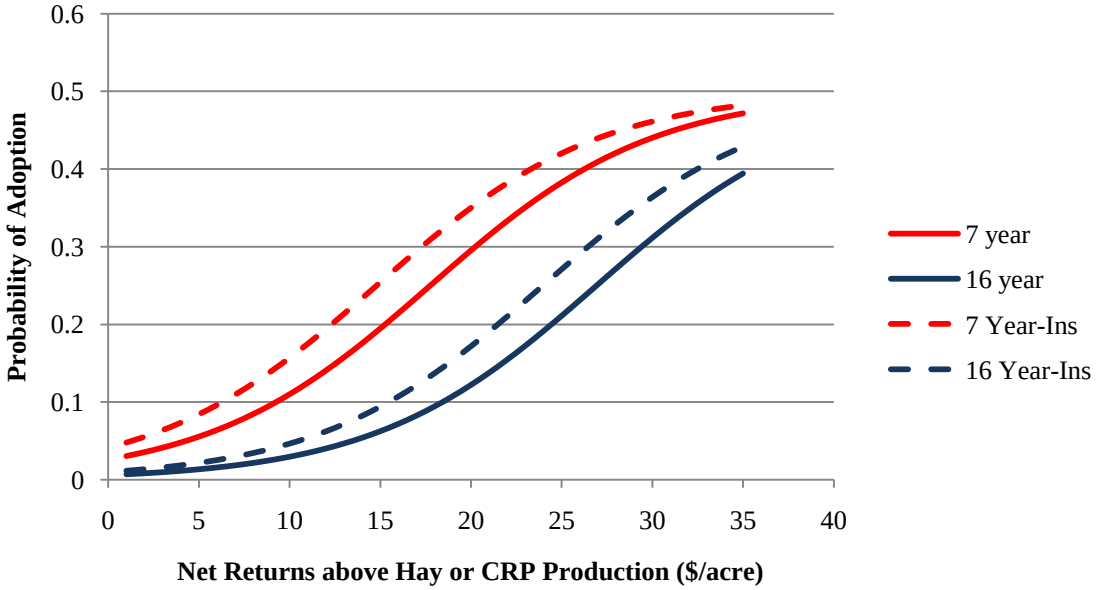

Figure 7. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; 35% cost share; central Kansas.

Farmers in western Kansas have nearly identical probabilities of adoption as those in northeastern Kansas. While climates differ much between the two areas, higher amounts of irrigated land in western Kansas allow farmers to grow crops such as corn and soybeans, similar to those in northeastern Kansas. Central Kansas farmers do not have the same opportunities for

crops these crops due to less rainfall than northeastern Kansas, and less irrigation than western Kansas.

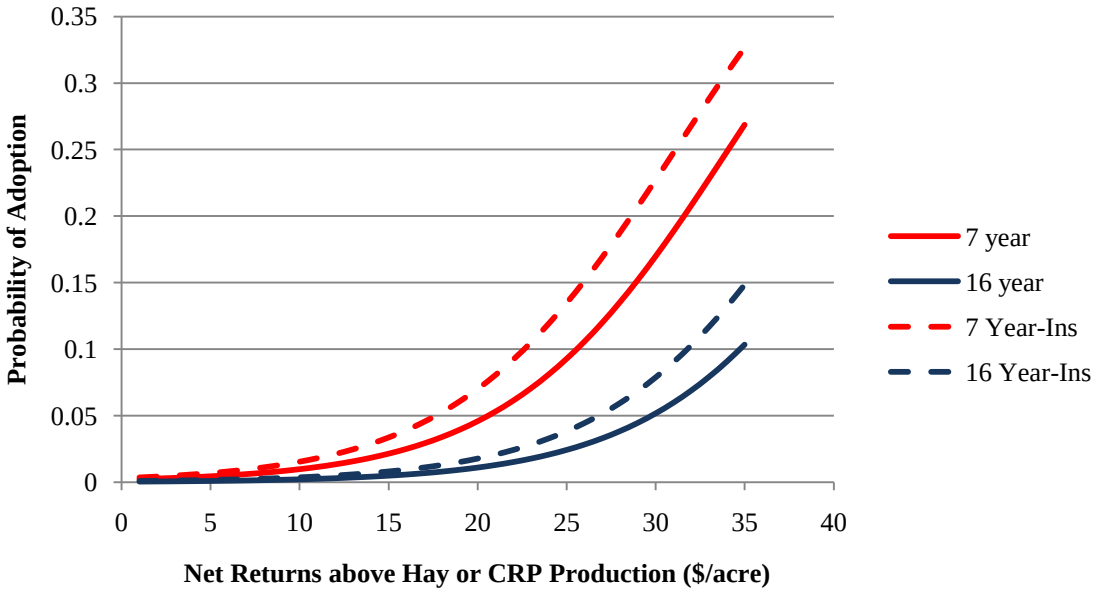

Figure 8. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; no cost share; western Kansas.

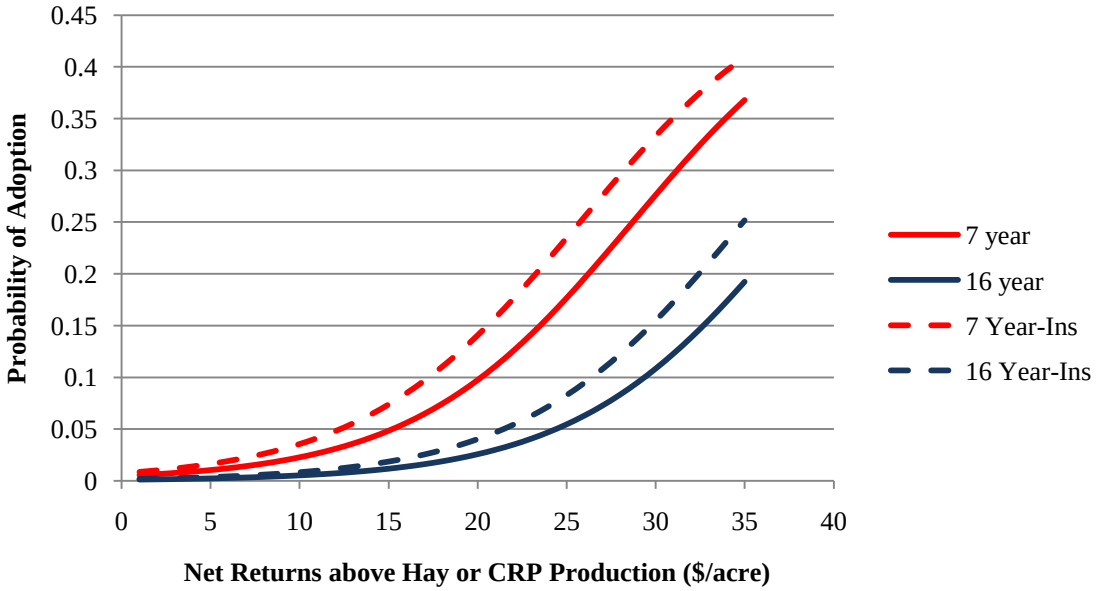

Figure 9. Probability of contract adoption for switchgrass for different levels of net returns and contract lengths with/without insurance; 35% cost share; western Kansas.

Marginal Effects

Marginal effects show the change in the probability of adopting alternative contracts at varying net return levels. Using the probability, *P*, above, the marginal effect is calculated as the derivative with respect to X_i, where *i* is the attribute of interest, here net returns, to find the marginal effect of a change in net returns on the probability of adopting a contract:

$$\begin{aligned} \partial P / \partial X_1 &= P\beta_1 - 2P^2\beta_1 \\ &= (P - 2P^2)\beta_1 \\ &= P(1-2P)\beta_1 \end{aligned} \tag{5}$$

The figures below show the marginal effects of a one-dollar increase in net returns on the probability of contract option in the three sampled areas of Kansas. For northeast Kansas, the marginal effects of adoption indicate that farmers have about a 0.01 probability of adopting a 7-year contract with insurance at a net return of $21 per acre above hay production but require about $24 to adopt without insurance, as shown in Figure 10. Figure 11 indicates that central Kansas farmers have an increased probability of adoption of 0.01 for a 7-year contract when net returns above hay production are only $9 and $12 with and without insurance, respectively. This compares to the $20 or more for the same contract required by farmers in the northeastern and western parts of the state (Figure 10 and Figure 12, respectively). In northeast and western Kansas, farmers will require more than $35 per acre over hay production to enter into 16-year contracts.

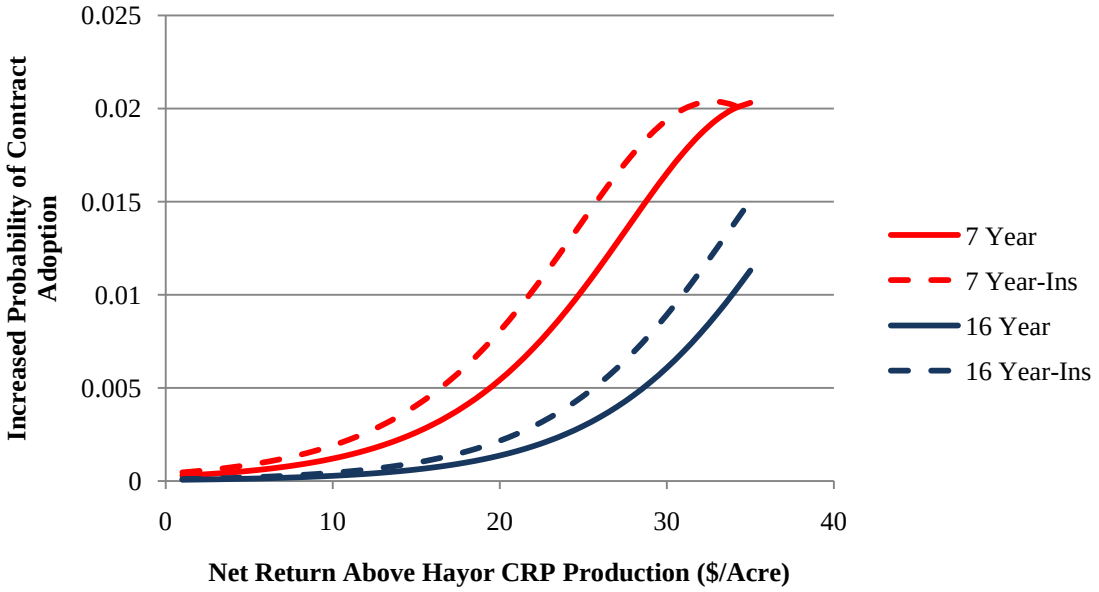

Figure 10. Marginal effect of a $1 increase in net returns above hay production for different length contracts with/without insurance; no cost share; northeast Kansas.

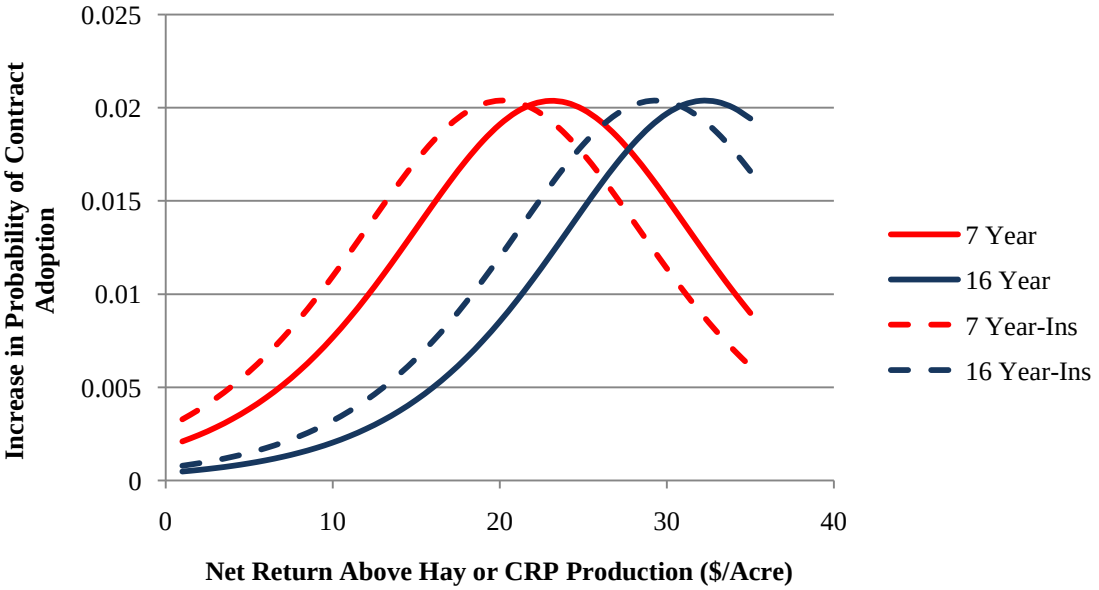

Figure 11. Marginal effect of a $1 increase in net returns above hay production for different length contracts with/without insurance; no cost share; central Kansas.

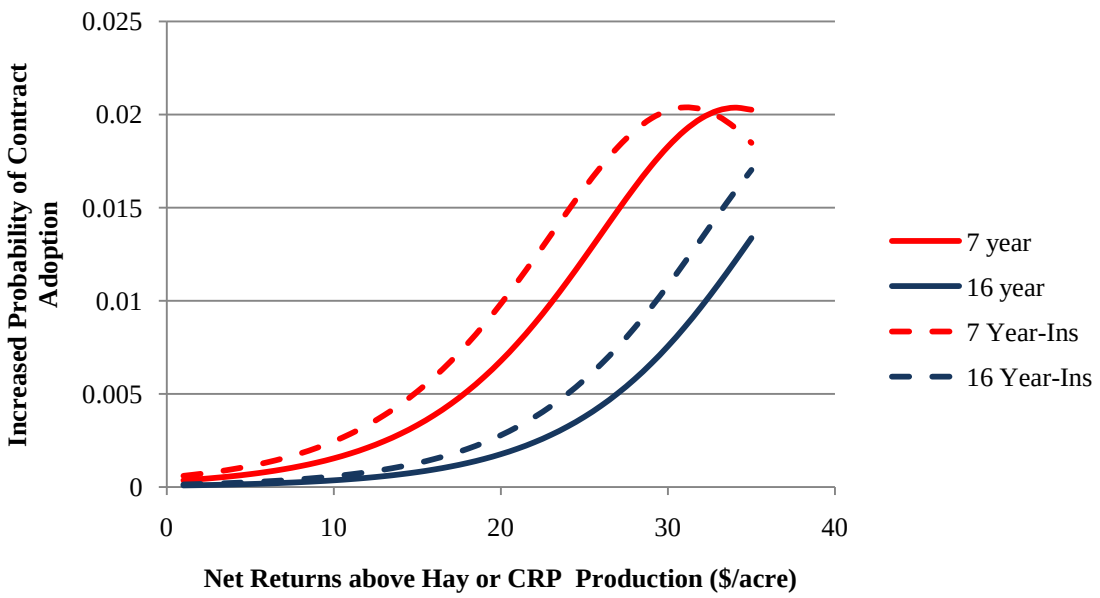

Figure 12. Marginal effect of a $1 increase in net returns above hay production for different length contracts with/without insurance; no cost share; western Kansas.

Willingness to Pay

Table 4 indicates farmers' willingness to pay (WTP) for various contract attributes for some net return above hay production or CRP. WTP is defined as β_1/β_i following Hensher, Rose, and Greene (2005), where β_i is the parameter for attribute i = contract length, biorefinery harvest, insurance, and seed cost-share. As expected, the negative sign on contract length indicates farmers are less willing to pay for longer contracts, but positive signs on the other attributes indicate they are willing to pay for these attributes. Farmers require about $1 per acre per year of additional contract length to enter into a contract. This result is also evident in the marginal effects calculations. Farmers are willing to pay about $2 per acre for the biorefinery to harvest if the biorefinery provides the option. Interpreting the insurance availability WTP estimate requires caution. While the calculated amount in Table 4 is $1.48 per acre for the insurance option, this value will only appear if the attribute is included in the stated choice experiment or not. Since it is included and the variable is effects coded (Insurance = 1, No Insurance = -1) then the value

farmers require to adopt a contract option with insurance versus no insurance is $2.96 per acre ($1.48 x 2). Finally, farmers' WTP for the cost share attribute is $0.15 per acre per one percentage increase in seed-cost share, *ceteris paribus*.

Table 4. Willingness to pay estimates for returns versus other contract attributes

Attribute	WTP	Std. Error[a]	t-stat
Contract length	-1.02	0.112056	-9.08834
Biorefinery harvest	2.09	0.480253	4.356085
Insurance	1.48	0.514751	2.872317
Seed cost share	0.15	0.018699	8.202431

[a] Standard errors are calculated via the delta method. All variables are significant at the 1% level.

Regardless of contract length, farmers require $2.96 per acre more to accept a contract without insurance than one with insurance. The probability of adopting a contract, A or B, is 0.50. Based on this probability, the change in net returns above hay production or CRP between the insurance options is calculated and shown in Table 5 below.

Table 5. Difference in net returns required to adopt non-insurance contract at 50% probability.

	7-year	16-year
Insurance	32.76	40.29
No Insurance	35.72	43.23
Difference	$2.96	$2.96

Conclusions and Further Research

Switchgrass has great potential to help reduce the nation's dependence on nonrenewable sources of energy, but much uncertainty exists as to its viability in Kansas. Kansas farmers were surveyed to assess their willingness to grow switchgrass as a biofuel feedstock under alternative contract scenarios. Results show that contract attributes positively affecting farmers' decisions include net returns, biorefinery harvest options, insurance availability, and a seed cost-share. Contract length negatively affects farmers' decisions on which contract to choose, opting for shorter-term contracts.

Farmers have less than a 50% chance of adopting switchgrass as a biofuel feedstock in any of the contract scenarios, largely due to the long-term nature of switchgrass production and uncertainty. In addition, switchgrass production's net return is not competitive with existing crops at this time. An area needing further study is biomass pricing based on farmers' willingness to adopt certain contract attributes.

An error components random effects logit model was run to predict the likelihood farmers would choose to adopt a contract over "opting out." The error components take into consideration unobserved random effects among individual decision makers.

A primary area of further research is to include more farm characteristic and demographic factors that affect decisions. In addition, bioenergy crop characteristics, storage, and transportation issues likely affect farmers' decisions to grow a bioenergy crops and should be included in the estimation. Risk aversion is also important when assessing farmers' willingness to adopt new technology or practices and could affect their decisions. While the error components model presented here controls for these, it does not help explain how farmers base their decisions because of these characteristics.

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