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Willingness of Kansas Farm Managers to Produce Alternative Cellulosic Biofuel Feedstocks: An Analysis of Adoption and Initial Acreage Allocation

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Abstract

This paper examines the likelihood that farm managers would be willing to harvest crop residue, or grow a dedicated annual or perennial bioenergy crop. In addition, factors affecting how many initial acres adopters would be willing to plant of a dedicated annual or perennial bioenergy crop are assessed. The study finds several factors affect farm managers' decisions to harvest crop residue, or grow annual or perennial bioenergy crops, as well as their potential initial acreage allocation decisions. These factors lead to several policy implications that should be tailored to the specific type of cellulosic bioenergy crop.

JEL Codes: Q12, Q15, Q16

Keywords: acreage allocation, annual bioenergy crop, cellulosic biofuel feedstock, crop residue, selection model, perennial bioenergy crop, willingness to grow

Willingness of Kansas Farm Managers to Produce Alternative Cellulosic Biofuel Feedstocks: An Analysis of Adoption and Initial Acreage Allocation

1. Introduction

The production of biofuels from cellulosic feedstocks continues to fall short of yearly standards set by the Environmental Protection Agency (EPA). The original Renewable Fuels Standard (RFS) set volume goals for biofuels through 2022. Since the original rule making, the EPA has decreased the required volume for conventional, cellulosic and advanced biofuels from 2014 through 2016 (2017 for biomass-based diesel) and has issued a proposal through 2017 (2018 for biomass-based diesel). The decrease in the total ethanol goal was from 18.15 billion gallons to 16.28 in 2014, 20.5 billion gallons to 16.93 in 2015 and 22.25 billion gallons to 18.11 in 2016, and preliminary for 2017, 24.0 to 18.8 billion gallons (Irwin and Good, 2016). The volume decrease for conventional, cellulosic, and advanced biofuels has been essential primarily because fuel consumption for vehicles is lower now than when the EPA originally made the rule. This has led to a lower demand for biofuel than originally anticipated. In addition, second generation biofuels, like cellulosic biofuel, have not been able to be produced in large enough quantities to meet the volume goals.

The shortfall in cellulosic biofuel production is due to several factors which has led to the proposed 2017 RFS to reduce the volume of cellulosic biofuel production for 2017 by over 5 billion gallons to 312 million gallons (Irwin and Good 2016). The factors that affect cellulosic biofuel's economic feasibility include technology, input and output prices, and government policy. In order to make enough cellulosic biofuel to meet government policies and for the cellulosic industry to be viable, it is important to know if farm managers are willing to produce the alternative cellulosic feedstocks needed for advanced biofuels production and how much of it they may be willing to produce.

This study examines three sources of cellulosic feedstocks and the probability a farm manager would be willing to produce one or more of these feedstocks. The first source is agricultural residue (e.g. corn stover), which represents a value-added product for farm managers. The other two types are dedicated annual bioenergy crops (e.g. energy or sweet sorghum) and perennial bioenergy crops (e.g. switchgrass). This study contributes to the existing literature by examining the effect of farm, farm manager, and socioeconomic characteristics on Kansas farm managers' willingness to produce alternative cellulosic feedstocks under a favorable contract. This paper extends initial efforts to consider a dedicated annual bioenergy crop and how many acres Kansas farm managers may be initially willing to grow both annual and perennial bioenergy crops.

Current literature has examined what types of contracts may be required to adopt different feedstocks (e.g. Bergtold, et al. 2014; Paulrud and Laitila 2010; Sherrington, et al. 2008). Other literature points to the fact that other considerations, in addition to profitability, may prevent adoption (e.g. Pannell, et al. 2006). Thus, this study examines the impact of these other factors, assuming a favorable contract is obtained. The study goes a step further to analyze the potential initial acreage allocation decisions for dedicated annual and perennial feedstock production once a contract has been signed, providing an initial estimate of the potential supply at the farm level. Lastly, several policies are suggested based on the findings.

A trivariate probit model is used to jointly determine farm manager willingness to harvest their crop residue and to grow dedicated bioenergy crops under a favorable contract. A second stage model is then used to determine how many acres a farm manager would be willing to initially plant of a bioenergy crop conditional on their self-selection to adopt that bioenergy crop. There have been several studies conducted on farm managers' willingness to grow perennial and herbaceous crops as bioenergy feedstocks and harvest crop residues.

2. Cellulosic Feedstock Descriptions

This study evaluates three cellulosic feedstock options that each represent a different type of bioenergy feedstock. Option 1 (Value Added Feedstock Option) represents the collection of crop residues. Option 2 (Dedicated Annual Bioenergy Crops) represents the growing of an annual energy feedstock crop. Option 3 (Dedicated Perennial Bioenergy Crops) assumes that the feedstock is a perennial. All three feedstock options present unique challenges and opportunities for crop producers.

Value Added Feedstock Option: Corn grain has been used as a bioenergy crop for years. However, biofuel mandates cannot be met with the use of only corn (and sorghum) grain to produce ethanol. Thus, biofuel producers may consider the use of corn stover or other agricultural residues (e.g. sorghum stover, wheat straw, etc.). The harvesting of agricultural residues has to be balanced against the ecosystem services they provide on the field, which include protection against soil erosion from wind and rain (Blanco-Canqui and Lal 2009); provision and storage of nutrients in the soil as residues decompose (Hess, et al. 2009); improvement of soil water storage and water use efficiency (Wilhelm, et al. 2007); and as a potential feedstock or bedding for livestock.

Dedicated Annual Bioenergy Crops: Dedicated annual bioenergy crops provide a potentially flexible alternative cash crop for farm managers as they can be grown in traditional crop rotations. For example, sweet, energy or forage sorghum varieties may serve as annual bioenergy crops. There are several advantages to these types of sorghum crops, including production of high amounts of biomass, drought tolerance and the ability to incorporate them into existing crop rotations (Calvino and Messing 2012).

Dedicated Perennial Bioenergy Crops: Dedicated perennial bioenergy crops may provide distinct advantages and disadvantages compared to the value added and dedicated annual bioenergy crops. Examples of these crops include switchgrass, miscanthus, and perennial grasses. As an example of the distinct advantages and disadvantages, consider switchgrass. This perennial option needs relatively low amounts of water and nutrient inputs to be productive, making it a good choice to plant on marginal land (Sanderson and Adler 2008). In addition, switchgrass can have positive effects on soil erosion and provide numerous environmental benefits. A potential disadvantage of switchgrass is it has a long establishment period of two to three years (Sanderson and Adler 2008). This implies that the land will be tied up for a longer period making it harder for farm managers to convert this land use due to changing market conditions. Further, establishment costs cannot be recouped in the first two to three years because farm managers will not be able to harvest their crop until it is well established or will only be able to harvest a small amount of crop until after a two to three year establishment period.

3. Background

A great deal of research has been conducted on the technical feasibility of growing cellulosic biofuels, as well as farmgate and breakeven pricing (Babcock, et al. 2007; Bangsund, DeVuyst, and Leistritz 2008; Gallagher, et al. 2003; Graham, et al. 2007; Graham 1994; Larson, et al. 2005; Mapemba and Epplin 2004; Paine, et al. 1996; Rajagopal, et al. 2007; Walsh, et al. 2003). While other studies have focused on biomass yield and production potential (Epplin, et al. 2007; Gallagher, et al. 2003; Graham, et al. 2007; Larson, English, and He 2008; Mapemba and Epplin 2004; McLaughlin, et al. 2002; Nelson 2002; Perlack, et al. 2005; Perrin, et al. 2008; Propheter, et al. 2010; Turhollow 1994; Walsh, et al. 2003). These studies do not evaluate farm managers' willingness to use their resources to produce a bioenergy feedstock. Nor do they identify the characteristics of the farm manager that would provide that feedstock.

Several studies have examined the opportunity costs of growing bioenergy crops or removing residue for biomass as an alternative to traditional cropping practices (Blanco-Canqui and Lal 2009; Gallagher, et al. 2003; Hess, et al. 2009; Wilhelm, et al. 2007). Baker and Galik (2009); McLaughlin, et al. (2002); and Paine, et al. (1996) examined environmental issues associated with the production of bioenergy feedstocks. McLaughlin, et al. (2002) and Paine, et al. (1996) also summarize the environmental benefits associated with growing dedicated bioenergy crops.

There have only been a few studies that have examined the willingness of farm managers to grow cellulosic biofuels. Using a survey of Tennessee farm managers Jensen, et al. (2006) found farms that are smaller in size, plant soybeans, have younger and more highly educated operators, and utilize conservation practices (e.g. no-till) are more willing to grow bioenergy crops. They found that farm managers who own or have access to equipment for hay production are more willing to plant switchgrass, indicating they have the capability to cut, bale, and handle switchgrass without additional capital investment. However, livestock operators are less likely to adopt switchgrass (Jensen, et al. 2006), potentially given the opportunity cost of converting land from pasture or hay production to bioenergy crop production.

Using a mail survey of farm managers in 12 southeastern states, Qualls et al. (2012) found that farm managers with beef cattle and older farm managers are less likely to be interested in growing switchgrass. Farm managers who own haying equipment and have hired a custom harvester are more likely to be interested in producing switchgrass (Qualls et al. 2012). Qualls et al. (2012) also looked at how many initial acres farm managers would be willing to devote to growing switchgrass, if they have interest. They found that farm size and raising beef cattle had a negative effect on the share of land farm managers are willing to devote to growing switchgrass; while older farm managers and farm managers who have used a custom harvester are willing to devote a higher share of land to the production of switchgrass (Qualls et al. 2012).

Sherrington, Bartley, and Moran (2008) used focus groups of farm managers in the United Kingdom to determine whether or not farm managers are willing to grow an energy crop. They found the main factors affecting willingness to adopt are farm managers' perceptions of financial returns and uncertainty in financial returns (at least) in the short-run. The study also found that farm managers, especially older farm managers, would be willing to contract bioenergy crop production on their operation to a third party.

A choice experiment conducted by Paulrud and Laitila (2010) examined farm and farm manager characteristics that may influence farm manager willingness to grow bioenergy crops, especially herbaceous and perennial crop options. The study found that production on leased or rented land, share of land set-aside for production, and the type of farming had no significant effect on farm manager willingness to grow. The age of the farm manager, farm size, income, cultivating on set-aside land, and geographical location had negative effects on farm manager willingness to grow.

Pannell, et al. (2006) found that the level of education has less to do with adoption than training courses related to the particular technology being adopted. They also concluded that crops with long time lags between planting and harvesting have increased production risk. Therefore the production of perennial bioenergy crops may be perceived as more risky than annual crops.

Using in-person interviews, Hipple and Duffy (2002) found that farm managers in Iowa base their decision to grow switchgrass, a dedicated perennial bioenergy crop, on profitability, return on investment, and economic sustainability. Farm managers also consider how adding switchgrass will fit with their current farming practices including its compatibility with land tenure and acreage control and with off-farm employment. Other important considerations are capital requirements, how complex growing switchgrass is, and the likely rewards. Quality of life issues were also taken into account including compatibility with personal and family values and beliefs, health and safety, environmental, and aesthetic issues. They also found that some farm managers believe that the advantages of adopting switchgrass are erosion control, enhanced water quality, wildlife habitat, and livestock feed and bedding.

Bransby (1998) looked at Alabama farm manager willingness to grow switchgrass, a dedicated perennial bioenergy crop and found that with favorable net profits, farm managers in the Black Belt of Alabama in 1997 would be willing to plant, on average, 254 acres of switchgrass. This was an increase from 1994 when farm managers in the same region were only willing to plant, on average, 155 acres.

Contractual arrangements with individuals or groups of producers (*e.g.* via a cooperative) is likely necessary to ensure an adequate supply of feedstocks in the long-term (Rajagopal *et al*. 2007; Epplin *et al*. 2007). Fewell, et al. (2013) provide a summary of the data collected from a survey of farm managers in Kansas designed to assess farms' willingness to harvest biomass as a valued added crop such as grain crop residue and perennial crop. The percentage of farm managers surveyed willing to produce and harvest biomass is reported along with reasons they would or would not grow and harvest biomass under a favorable contract with a bio refinery. The percent willing to adopt ranged from 25 to 68.5 percent depending upon the type of crop and region of the state. Farm managers indicated the important factors affecting their decision to adopt or not were net returns, contract length, uncertainty, and nutrient replacement.

Bergtold et al. (2014) examine farm managers' willingness to produce alternative cellulosic feedstocks under different contractual, market, and harvesting arrangements using stated choice experiments and a random utility framework to model farm managers' decisions. The contractual attributes that increase the likelihood of feedstock enterprise adoption are net returns above the next best alternative use of the land, contract length, cost-share, financial incentives, insurance, and custom harvest options. These two studies examined what favorable market and contractual conditions would need to be for farm managers to produce biofuel feedstocks. What is ultimately favorable to individual managers will be farm manager and feedstock specific and will need to be negotiated with the processor or refinery.

Skevas et al. (2016) examined landowners' willingness to rent out their land (crop land, pasture and marginal land) for production of bioenergy feedstocks (corn, poplar, prairie grass and switchgrass) in southern lower Michigan. They did not examine dedicated annual bioenergy crops. Even at rental rates three times larger than the average rental rate in the study region, land owners were not willing to rent out large portions of their land for bioenergy crop production. Landowners were even less willing to rent out land that was considered marginal. At rental rates over $100/acre, land owners were willing to rent out over 120 acres of crop land, while it was around 90 acres for pasture and marginal land.

Song et al. (2011) examine land conversion to switchgrass under uncertainty and cost reversibility. They find that the level of net returns per acre to convert from a corn-soybean rotation to switchgrass production is almost double the returns per acre from switchgrass production using a real options modeling framework, even when switchgrass production has higher returns than the corn-soybean rotation,. This finding is likely due to the possibility of costly reversibility for converting production from one land use to another.

This study expands on the prior two studies by the authors, as well as the growing body of literature, by examining the joint adoption of three broad categories of cellulosic feedstocks (instead of specific feedstocks) that can be provided by agricultural producers, especially the adoption of annual bioenergy crops, which has not received as much attention in the economics literature. It goes beyond just contractual adoption to examine the joint adoption of these three feedstocks as well as farm managers' potential initial acreage allocations. While literature has examined what kind of contractual relationship is required to adopt one of these feedstock enterprises (e.g. Bergtold et al., 2014), it has not examined what kind of commitment a farmer may initially make in terms of land-use in the Midwest. In addition, other factors may impact the adoption decision, beyond a favorable contract. Thus, this study begins by assuming a favorable contract to elicit the other factors that may affect adoption of a feedstock enterprise and the level of adoption farmers' may initially commit to under said contract.

4. Methods and Data

Discrete choice and selection models are used with survey data collected from farm managers by enumerators to examine factors that affect farm manager willingness to supply bioenergy crops and to determine the minimum initial acres they would be willing to plant of annual or perennial bioenergy crops given a favorable contract.

4.1 Conceptual Framework

The decision is assumed to be two-staged sequential process. In the first stage, an expected utility framework is used to determine the factors affecting farm manager willingness to harvest crop residue and/or grow a dedicated annual or perennial bioenergy crop under a favorable contract. A favorable contract is defined here as a contract that provides for a positive net return to feedstock production and mutually beneficial conditions between the farmer and the ethanol refinery (or other intermediate processor). It is not assumed that production under the contract will provide a higher net return than other uses of the land (e.g. production of another crop or grazing). In the second stage, an expected profit framework is used to determine the factors affecting a farm manager's decision on the potential initial acreage allocations for planting a dedicated annual or perennial bioenergy crop, given they have decided to grow one. A profit framework is adopted at the second stage of the model to account of the tradeoffs of allocating land to different uses. For the purpose of this study, the farm manager is the individual who makes the decisions for the farm operation. The farm manager may be the owner of or leasing the land and equipment. Most farm managers in Kansas both own and lease land to farm.

4.1.1 Stage 1 - Cellulosic Feedstock Adoption

In this stage of the framework, it is assumed the three different types of cellulosic feedstock enterprises being examined are weakly separable (Coyle, 1993). This assumption is based on the idea that the three types of feedstocks examined differ. When crop residue is harvested following grain harvest a value-added enterprise is created, but the primary return is likely to come from the cash crop and not the harvesting of the residue. An annual bioenergy crop can replace a traditional crop in a rotation and becomes a cash crop for the farm manager. A perennial bioenergy crop will likely be planted on marginal land or replace another perennial cash crop, such as hay production. A farmer has the option of planting none, one, or up to all three of the feedstocks on their farm. Farmers are not limited in the model to adopting a single feedstock. Thus, the framework allows for the joint adoption of multiple feedstocks.

Farm manager i's overall expected utility function (V_i^E) for the adoption of a cellulosic feedstock is given by:

(1) $$V_i^E\left(V_{r,j,i}^E, V_{a,j,i}^E, V_{p,j,i}^E\right),$$

where V_i^E is weakly separable between the biofuel feedstock enterprises. The second stage expected utility functions are

(2) $$V_{c,j,i}^E(\pi_{c,i}^E\left(X_{c,i}\right), Z_{c,i}),$$

for farm manager *i* where $c = r, a, p$ and $j = 1,0$. The index *c* represents the cellulosic feedstock being adopted, where *r* is harvesting of crop residue; *a* is a dedicated annual bioenergy crop; and p is a dedicated perennial energy crop. $\pi_{c,i}^E\left(X_{c,i}\right)$ is the restricted expected profit function for producing feedstock option *c* for farm manager *i* (Miller and Platinga, 1999); and $X_{c,i}$ is a set of explanatory variables that impact the expected returns from producing cellulosic feedstock c for farm manager i, which includes acreage of the operation, percent of leased land, and location of the farm. It is assumed that V_i^E is increasing in each $V_{c,j,i}^E$, and that $V_{c,j,i}^E$ is a monotonically increasing function of $\pi^E_{c,i}$. This implies that maximizing $\pi^E_{c,i}$ will increase expected utility. Expected utility is used at this stage, as it is a function of other factors that affect the shape of the utility function that may not be strictly related to profit maximization, such as farm manager perceptions; age and other demographics; and employment (Barry and Baker, 1977; Skaggs et al., 1994). Thus, $Z_{c,i}$ is a set of explanatory variables that directly impacts expected utility of producing feedstock *c* for farm manager *i*. The index *j* represents two different states and is equal to "1" if crop residue is harvested or a dedicated energy crop is grown and "0" otherwise. For the remainder of the methods section, the index *i* representing the farm manager under consideration is suppressed to ease notational burden.

Farm manager *i* will produce cellulosic feedstock *c* if the expected utility from producing a cellulosic feedstock is greater than if it is not produced. Given the weakly separable nature of the expected utility function and that it is assumed it is increasing in the sub-utility function for each crop, a farm manager will harvest crop residue or grow a dedicated energy crop if

(3) $$\Delta V^E_c = V^E_{c,1}(\pi^E_c(X_c), Z_c) - V^E_{c,0}(\pi^E_c(X_c), Z_c) > 0.$$

4.1.2 Stage 2 - Initial Acreage Allocation

The second stage decision examines the initial allocation of acreage to planting a dedicated annual or perennial bioenergy crop, given the farm manager has decided they are willing to grow a dedicated annual or perennial bioenergy crop. For a given farm manager, it is assumed that the initial acreage allocation decision is not affected by Z_c, but is determined by what will maximize restricted expected profit, $\pi^E_{c,i}(X_{c,i})$, for the farm manager. In the second stage of the model, it is assumed that the enterprises of producing dedicated annual and/or perennial bioenergy crops are strongly separable or disjoint. That is, the expected restricted profit function is additive in the expected restricted profit functions for each enterprise (Coyle, 1993). First, the type of land likely to be allocated for the production of each type of dedicated bioenergy crop is assumed to be different. An annual bioenergy crop is likely to be planted in rotation with another cash crop, while a perennial bioenergy crop is a good option for marginal land or prior hay or grassland (Anand et al., 2011). Second, this stage of the model is in essence a trialing phase, as it would be the initial acreage allocation after the decision to adopt (Abadi Ghadim and Pannell, 1999). Thus, it is assumed that the areas initially planted for each crop will be small and may not be restricted by shared machinery and other production decisions on this small scale.

Following Miller and Platinga (1999) and given the assumption of strong separability, if the farm manager decides to adopt biofuel feedstock(s) c (i.e. $\Delta V_c > 0$), then the farm manager will choose the initial land allocation to plant the crop by maximizing the total expected restricted profit function:

(4) $$\sum_c \pi_c^E(A_c, X_c) + \pi_{\bar{A}}^E(\bar{A}, \bar{X})$$

subject to

(5) $$\sum_C A_c + \bar{A} = L,$$

where A_c is the initial land allocation to feedstock c; $\pi_{\bar{A}}^E(\bar{A}, \bar{X})$ is the restricted expected profit function for all other crop production; $\bar{A}$ is the land allocated to all other crops; $\bar{X}$ are the other factors impacting restricted expected profit for other crop production; L is the total area of land available to plant annual and perennial crops; and $(A_c, \bar{A}) \geq 0$. The Kuhn-Tucker solution to the optimization problem given by equations (4) and (5) for A_c is the optimal initial allocation of land to plant to an annual and/or perennial bioenergy crop, i.e. $A_C^* = f(X_c, L)$ (following the modeling approach by Miller and Platinga, 1999).

4.2 Survey Data

A survey was administered from November 2010 to February 2011 by Kansas State University and the United States Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) to assess Kansas farm manager willingness to produce alternative cellulosic biomass feedstocks for bioenergy production. A total of 485 farm managers were contacted in northeastern, central, and western Kansas to participate in the survey. These regions of Kansas were selected based on the number of farms growing corn and/or sorghum; mix of irrigated and dryland production; geographical and climate differences; and proximity to existing grain-based and potential future add-on cellulosic-based biorefineries[1]. Western Kansas has the most irrigation out of the three areas in the study, providing a means to capture behavior by farm managers who irrigate crops, particularly corn. The central part of the state has less irrigation than the west, but is the largest producer of sorghum in the state. A significant dedicated annual bioenergy crop suited to Kansas is energy sorghum. The northeastern part of the state relies less on irrigation than the other two areas and has more rainfall. The main crops produced in the northeastern part of the state are corn and soybeans. The three regions examined provide some generalizability for analyses conducted here for the Central Great Plains and states bordering Kansas (see table 1 and explanation below). Figure 1 provides a map of the counties surveyed.

For each county in each region of Kansas surveyed, a random sample of farms with at least: (i) 260 acres of crop production; and (ii) $50,000 in annual gross farm sales, were obtained from the USDA-NASS farm manager list. The size and sales limitations were used to target more commercial level operations for the sample of farm managers surveyed. In addition, the percentage of dryland versus irrigated farms surveyed was selected to match the existing distribution of the percentage of dryland versus irrigated farms for each region based on the distributional data that USDA-NASS possessed when they pulled the sample of farms from the entire farm population. Thus, the population of farm managers examined in this study is for medium to large commercial operations that grow crops in Kansas. Farm managers already participating in USDA-NASS enumerated surveys (e.g. ARMS) were removed from the sample and replaced with another randomly drawn farm manager. The survey was tested using face-to-face interviews with farm managers in the targeted study areas of the state.

Of the 485 farm managers contacted, 290 completed the survey and 38 were out-of-business, did not farm, or could not be located. Thus, the final survey response rate was 65%. Of the 290 respondents who completed the survey, 203 responses were usable for analysis examining value-added crops, annual bioenergy crops, and perennial bioenergy crops, respectively (given their potential joint adoption). The lower numbers of responses for this analysis was due to a lack of response or refusal to answer all relevant questions. Of the regions surveyed, 61 respondents were from western Kansas, 75 were from central Kansas, and the remaining 67 respondents were from northeastern Kansas.

Farm manager demographics taken from the 2012 U.S. Census of Agriculture (USDA-NASS, 2013) were used to compare survey respondents to representative Kansas farm managers. Table 1 compares some of the demographics as reported by farm managers in the survey to statewide numbers as recorded in the 2012 Census of Agriculture. Descriptive statistics calculated using Agricultural Census data were done for farms above 260 acres in size and $50,000 in gross farm sales when applicable. The average age of surveyed farm managers was slightly lower than the Census average. Average farm size and the amount of land rented were larger than the Census averages for Kansas, but the average amount of permanent pasture was less. While these averages may not be significantly different, the differences may be due to the targeted areas for the survey within the state. The survey asked respondents to choose a category in which their value of agricultural product sales occurred, the Census of Agriculture figure of $448,317 was slightly larger than the most often selected category of $200,000 to $399,999 by respondents on the survey. When comparing the averages to the bordering states of Nebraska, Colorado and Oklahoma for generalizability, similar results are found. The authors feel that the differences may not be that substantial given heterogeneity in the sample and across the states, providing evidence that the results of this study should be applicable to the surrounding states. Difference may be due to the difference in the commodity market values in the year the survey was done and when the Census was completed, as well.

The survey was used to determine if farm managers are willing to produce any of three different bioenergy crops: crop residues (e.g. corn stover) as a value-added product; a dedicated annual bioenergy crop option (e.g. sweet sorghum); or a dedicated perennial bioenergy crop (e.g. switchgrass). Respondents could indicate if they were willing to adopt none, one or more feedstock enterprises. There were farmers, who were not willing to adopt any of the enterprises. Figure 2 contains the questions asked in the survey. It should be emphasized that the conditional formulation of the questions in figure 2 does affect the econometric model formulated in the model section of the paper. Furthermore, it should be noted that the respondents were instructed to make several assumptions to assist them in answering the questions. The first was that respondents were to answer as if a favorable contract was offered. It was assumed that a favorable contract would have a positive net return, but would not necessarily lead to adoption. Other enterprises may have higher net returns. Therefore, consideration of opportunity costs and other factors (e.g. demographic and cultural) may affect the adoption decision. Contracts may be individually negotiated with farm managers and the question was designed to gauge farm managers' interest in growing the categories of feedstocks presented. In addition, respondents were also told to assume that the annual or perennial bioenergy crop (found in table 2) could be planted on leased or rented land.

Table 2 provides descriptions of the variables from the survey that are used in the analysis. The dependent variables are: would a farm manager be willing to harvest their value-added crop residue (*VA*); would a farm manager be willing to grow a dedicated annual bioenergy crop (*AC*); would a farm manager be willing to grow a dedicated perennial bioenergy crop (*PC*); and how many initial acres of the annual (*ACIA*) and perennial (*PCIA*) bioenergy crops would a farm manager be willing to grow (table 2). The independent variables are described by categories. The categories are farm characteristics, farm practices, and farm manager characteristics. The factors in each of these categories are the hypothesized variables that would affect a farm manager's adoption and initial acreage allocation decision for each type of cellulosic feedstock being considered based on previous studies examined in the literature and economic theory.

4.3 Empirical Modeling Framework

Following the conceptual framework laid out above, the empirical model follows a two-stage process that first jointly models the adoption decisions of the three feedstock categories and then models the initial acreage allocation decision conditioned on the adoption decision.

4.3.1 Stage 1 - Cellulosic Feedstock Adoption

Given the nature of utility, ΔV_c cannot actually be observed. Instead, the binary response from a farm manager willing to harvest crop residue or grow a dedicated bioenergy crop is observed implying that $j = 1$ if $\Delta V_c > 0$ and "0" otherwise. Assuming that the factors of each sub-expected utility functions for each feedstock enter linearly, the model for a farm manager willing to produce a given cellulosic feedstock is given by:

$$(6) \qquad \Delta \mathrm{V_c} = \boldsymbol{\alpha}_c' \mathbf{X_c} + \boldsymbol{\gamma}_c{}' \boldsymbol{Z}_c + \varepsilon_c \text{ with } \varepsilon_c \sim \mathrm{NI}(0, \sigma_\varepsilon^2) \text{ and } j_c = \begin{matrix} 1 \; if \; \Delta \mathrm{V}_c > 0 \\ 0 \; otherwise \end{matrix}$$

where $\boldsymbol{\alpha}_\mathbf{c}$ and $\boldsymbol{\gamma}_c$ are vectors of parameters. Given that ε_c is normally distributed and j_c is observed, the models given in equation (6) can be estimated as probit models.

While the decisions to adopt a biofuel feedstock may be weakly separable, they are likely related given it may affect the land use decisions concerning the overall crop mix on a farm; the relationships between biomass markets; usage of similar equipment; and timing of production decisions. That is, the decision to adopt a particular feedstock is correlated with the decision to adopt a different feedstock. Thus, the three separate probit adoption models given by equation (6) are likely correlated and need to be estimated simultaneously. Let Ω represent the correlation matrix between the error terms of the different crops and assume that the variances of the error ε_c are equal to 1 for $c = r,a,p$. The three error terms are jointly trivariate normal, i.e. $(\varepsilon_r, \varepsilon_a, \varepsilon_p) \sim N_M(\mathbf{0}, \Omega)$. Following Greene (2012), this gives rise to a trivariate probit model, which can be estimated using simulated maximum likelihood methods. The likelihood function involves calculating trivariate probabilities of the form:

$$(7) \quad L_i = \Phi_3\big(q_{i,r}(\boldsymbol{X'}_{i,r}\boldsymbol{\alpha}_r + \boldsymbol{Z'}_{i,r}\boldsymbol{\gamma}_r), q_{i,a}(\boldsymbol{X'}_{i,a}\boldsymbol{\alpha}_a + \boldsymbol{Z'}_{i,a}\boldsymbol{\gamma}_a), q_{i,p}(\boldsymbol{X'}_{i,p}\boldsymbol{\alpha}_p + \boldsymbol{Z'}_{i,p}\boldsymbol{\gamma}_p), \Omega^*\big),$$

where $q_{i,c} = 2\Delta \mathrm{V}_{i,c} - 1$; $\Omega_{jc}^* = q_{i,j} q_{i,c} \rho_{j,c}$;$j, c = r, a, p$; $j \neq c$; $\rho_{j,c}$ is the correlation between feedstocks j and c; and Φ_3 is the trivariate standard normal distribution (Greene, 2012). Monte Carlo simulation techniques are used to estimate the trivariate probabilities to maximize the likelihood function for the model to obtain estimates following Hajivassiliou and McFadden (1998). PROC QLIM in SAS was used to estimate the trivariate probit model. Marginal effects of a change in an explanatory variable on the unconditional marginal probability of adopting a particular feedstock type were estimated as partial average effects with asymptotic standard errors estimated using the method of Krinsky and Robb (Greene, 2012; Krinsky and Robb, 1986).

Many of the same variables defined in table 2 are used to estimate farm manager willingness to harvest crop residue or grow a dedicated annual or perennial bioenergy crop. Some variables are included in the probability of producing a particular feedstock and not in others, because the three types of cellulosic feedstocks examined differ. These differences are differences in production practices and investments needed to produce them. When crop residue is harvested following grain harvest a value-added enterprise is created. An annual bioenergy crop can replace a traditional crop in a rotation. A perennial bioenergy crop requires replacing a traditional annual crop or hay crop for five to ten years and it takes two to three years to establish. Since a dedicated perennial crop would not be harvested every year the use of conservation tillage practices would not come into play very often, so *CV Tillage* was not included in the dedicated perennial bioenergy crop model. However, *Percent CRP* is included in the dedicated perennial bioenergy crop model and not in the harvest crop residue or dedicated annual bioenergy crop models. This is because a dedicated perennial bioenergy crop and CRP are both likely to be planted on marginal land; whereas annual crops are more likely to be planted on more productive land. This is also why *Irrigate Crops* was not included in the perennial model[2]. A dedicated annual bioenergy crop would likely replace a crop in an established crop rotation whereas a change in crop rotation would not be necessary to harvest crop residue, which is why *Crop Rotation* was only included in the dedicated annual bioenergy crop model.

Based on previous studies (Jensen, et al. 2006; Pannell, et al. 2006; Paulrud and Laitila 2010; Sherrington, Bartley, and Moran 2008), farm managers with a college education; farm managers with less land; farm managers who currently practice conservation tillage; and farm managers who have used a baler will be more likely to grow a cellulosic feedstock. It is hypothesized that these results will hold in this study as well based on the following reasons. It is hypothesized that farm managers may be open to planting bioenergy crops that can potentially improve soil productivity and be incorporated into crop rotations. Farm managers with a college education may be more open to new opportunities and cropping options. Farm managers who practice conservation tillage may feel that the partial harvesting of crop residues may be a profitable practice, if it does not reduce soil productivity (Wilhelm et al., 2007). It is also hypothesized that farm managers who are risk avoiders may be less likely to grow a bioenergy feedstock due to potential uncertainty with the new crop and additional production risk and that farm managers who have a conservation plan may be less willing to harvest their crop residue, but may be more willing to grow a dedicated perennial bioenergy crop. These farm managers may be aware of crop residue needs for conservation purposes, allowing for partial harvesting. Furthermore, it is hypothesized that farm managers who already bale or graze their crop residue may be more likely to harvest their crop residue and/or grow a dedicated bioenergy crop, because the biomass feedstock may not interfere with their current grazing regime and from prior experience of harvesting and baling crop residues. On the other hand, it should be noted that these same farm managers could view the current use of their crop residue as an opportunity cost associated with removing residues for bioenergy production, which may result in a negative relationship. Finally, it is hypothesized that farm managers who currently have acres devoted to CRP land will be more willing to grow a dedicated perennial bioenergy crop, if allowed under

CRP provisions. If the CRP provisions are allowed, this would give farm managers an opportunity to make additional income on their CRP land.

4.3.2 Stage 2 - Initial Acreage Allocation

Recall, a two-part question was asked for the dedicated annual and perennial bioenergy crop options. A farm manager was asked if they would be willing to produce a bioenergy crop assuming favorable contractual terms, and if so, how many initial acres would they be willing to plant, assuming they could plant the crop on owned or rented acres (figure 2). Given the two-stage nature of the question asked in the survey and that in the conceptual framework the allocation decision is conditional on the decision to adopt, an empirical initial allocation model for each dedicated bioenergy crop in question must take into account possible self-selection bias. That is, respondents are self-selecting themselves into the group of respondents who are willing to grow dedicated annual bioenergy crops, which could bias parameter estimates and inference if not taken into account (Heckman 1979; Maddala 1983). To accommodate this, self-selection bias must be corrected for when modeling the initial acreage allocation decisions.

To develop the second stage of the empirical model, following the solution to the optimization problem given by equations (4) and (5) let A_c represent the initial number of acres a farm manager will be willing to plant of a dedicated bioenergy crop or feedstock option c. Given that $A_C^* = f(X_c, L)$ and assuming the functional relationship is linear, the initial acreage allocation decision can be represented by the following equation:

(8) $$A_c = \boldsymbol{\beta'}_{\boldsymbol{c}}\boldsymbol{X_c} + \beta_L L + u_c \text{ with } u_c \sim \text{NI}(0, \sigma_u^2),$$

where $(\boldsymbol{\beta_c}, \beta_L)$ is a vector of parameters to be estimated. Recall, that A_c will only occur if $j_c = 1$, which means that a farm manager has to be willing to grow a dedicated bioenergy crop in order to allocate acreage to the planting of the crop. Thus, the conditional mean of A_c as given by (Heckman 1979) is

$$(9) \qquad E(A_c|\boldsymbol{X}_c, L, j_c = 1) = \boldsymbol{\beta'}_c\boldsymbol{X_c} + \beta_L L + E(u_c|\boldsymbol{X}_c, L, j_c = 1).$$

The vector of explanatory variables $\boldsymbol{X_c}$ in the initial allocation model given by equation (4) is similar to those included in the probit models for the dedicated annual and perennial bioenergy crops and L is the total land on the farm.

To take account of the self-selection bias, in the second stage of the model, the decision made in the first stage of the model is taken into account. Given the limited degrees of freedom ($N = 203$), an approach similar to the conventional approach outlined by Maddala (1983) and Greene (2012) is used. It is assumed the second stage is only conditional on the marginal probability to adopt the crop being examined. Thus, the unconditional marginal probabilities of the choice to adopt a particular feedstock alternative is used to calculate the inverse Mills ratio to include in the regression for equation (6) in order to correct for self-selection bias. These unconditional probabilities are calculated as $\phi(a_c'X_c)$ and $\Phi(a_c'X_c)$ where ϕ and Φ are the standard normal probability and cumulative density functions; and $c = a,p$ (Greene, 2012). In addition, recall the trivariate probit model corrects for the correlation between the adoption decisions in the first stage of the model. Thus, the approach here adjusts for any potential self-selection by taking account of the fact that

$$(10) \qquad E(u_c|X_c, L, j_c = 1) = \rho\sigma_u \frac{\phi(a_c'X_c)}{\Phi(a_c'X_c)},$$

where ρ is the correlation between ε_c and u_c; and σ_u is the standard deviation of u_c. Thus, the term $\frac{\phi(a_c'X_c)}{\Phi(a_c'X_c)}$ is included as an additional covariate in the linear regression models estimated for the second stage initial allocation decision. If the parameter ρ is equal to zero, then no selectivity bias exists (Greene, 2012; Gourieroux 2000). The second stage of the model is estimated using PROC REG in SAS (2008).

There is little research examining how many acres farm managers may be willing to commit to the initial production of a dedicated bioenergy crop, especially an annual option. It is hypothesized that farms in the western part of the state will be willing to allocate more acres to bioenergy crop production than farms in other parts of the state. The western part of Kansas has twice as much CRP land as the rest of the state. With large tracts of CRP land still under contract in Kansas, if policy allows CRP land to be used for perennial biofuel feedstock production, then farm managers may be willing to plant perennial biofuel feedstock options on the land. In addition, it is hypothesized that *Graze Residue* and *Irrigate Crops* may decrease the amount of initial acres a farm manager is initially willing to plant of a dedicated bioenergy crop. Given the investment required for irrigation, it is likely the farm manager will allocate irrigated land to crops with a higher expected return and if land is currently used for grazing, planting a dedicated energy crop potentially reduces income from grazing. In addition, *West, Irrigate Crops,* and *Graze Residue* were interacted with *Total Acres* to determine if any interactions existed.

5. Results

Table 3 reports the results from the estimation of the trivariate probit model, while table 4 provides the estimation results for the initial acreage allocation decision models. Based on the ρ statistic in table 3, the decisions to produce the different feedstocks by farm managers are correlated with each other, supporting the use of the trivariate probit formulation to model the adoption decisions. That is, the results suggest that farm managers will consider the harvesting of crop residues as a value-added enterprise and the growing of a dedicated annual bioenergy crop jointly. Similarly, farm managers will consider the growing of dedicated annual and perennial bioenergy crops jointly, as well. Assessing the results for the initial acreage allocation models in table 4, the fitted inverse mills ratios in each dedicated bioenergy crop equation were not statistically significant, providing no significant evidence of self-selection bias. Thus, the equations could have been estimated independently of the trivariate probit model. Estimation results of independent initial allocation models did not change the results found here, so the selection model results are presented. The remainder of this section presents the results by each cellulosic feedstock type examined.

5.1 Crop Residues

The results indicate, with statistical significance, that farm managers who reside in western Kansas (*West*) are less likely to remove crop residue than other farm managers. These results make intuitive sense. Farm managers in western Kansas on average receive less rain fall than farm managers in other parts of Kansas. These farm managers may prefer leaving crop residue on the soil surface to help capture additional moisture in the soil that is needed for future cash crops. Furthermore, differences in cultural practices, geography and other unmodeled heterogeneity are likely captured by the inclusion of *West* in the model. Two interesting, yet insignificant variables are worth discussing. The study finds as Paulrud and Laitila (2010) did that leased land (*Percent Leased*) is insignificant in determining whether farm managers are willing to harvest crop residue. This implies that farm managers are likely indifferent between biomass removal on owned or leased land. In addition, being risk averse (*Risk Avoider*) is also insignificant. This may imply that farm managers do not see removing crop residue, under a favorable contractual agreement, as a risk increasing or decreasing activity.

5.2 Dedicated Annual Bioenergy Crop

Examining the unconditional marginal effects, there are several variables that are positive and statistically significant in the farm manager willingness to grow a dedicated annual bioenergy crop model. These variables include farm size (*Total Acres),* percent of land leased (*Percent Leased*), grazing of crop residue (*Graze Residue*), baling of crop residue (*Bale Residue*), and having off-farm income (*Off-Farm*). On the other hand, being more risk-averse (*Risk Avoider*) had a negative and statistically significant impact on willingness to grow a dedicated annual bioenergy crop.

The positive effect of *Total Acres* on farm manager willingness to grow a dedicated bioenergy crop is likely due to the fact that larger farm operations may have more land to allocate for trialing new crops, and these costs will be a smaller percent of total cost. *Percent Leased* indicates farm managers are more likely to produce annual bioenergy crops if they lease land. This may occur because farm managers believe landlords might be willing to allow an annual bioenergy crop to be planted as it can be grown in rotation with other cash crops. It is also worth noting that summary statistics show that farms, on average, typically rent more than half their acres. *Percent Leased* has a positive and statistically significant marginal effect of 0.25 implying that if a farm manager were to increase the percentage of land leased by 1% they would be 0.25% more likely to grow a dedicated annual bioenergy crop.

Graze Residue is positive, indicating farm managers who graze their crop residues and biomass are more likely to be willing to produce an annual bioenergy crop because it may provide additional opportunities for grazing. That is, the residue from a dedicated bioenergy crop may be usable for grazing, silage, and/or biofuel production (e.g. forage sorghum varieties).

Farm managers who currently bale their residue have the equipment required to harvest an annual bioenergy crop, which implies that they do not have to invest in new capital for crop harvest. Further, previous experience with baling reduces the uncertainty associated with conducting a new field operation. Graze residue and bale residue both have positive and statistically significant marginal effects. If a farm manager currently grazes or bales their crop residue they are 15% and 17% more likely to grow a dedicated annual bioenergy crop, respectively.

Of the farm characteristic variables, *Off-Farm* and *Risk Avoider* had statistically significant marginal effects. The presence of off-farm income increased the likelihood of adopting an annual dedicated bioenergy crop by 13%, as off-farm income may help to provide the ability for the farm manager to invest in new cropping enterprises and technologies. The significant and negative coefficient on *Risk Avoider* would seem to imply that growing an annual bioenergy crop is seen as a new and unproven enterprise leading to more risk. No spot markets for dedicated bioenergy crops currently exist, making it a highly uncertain enterprise for farm managers, who may be less likely to adopt such an enterprise (Pannell, et al. 2006; Rajagopal, et al. 2007). In addition, the adoption of a new crop may increase production risk for the farm manager due to uncertain yields and field performance. If someone is a risk avoider, then they are 15% less likely to grow a dedicated annual crop.

The unconditional mean initial number of acres to be planted of an annual bioenergy crop by farm managers who were willing to adopt is 122.2 acres. This initial allocation is positively and significantly affected by the variables *West, Total Acres, Off-Farm, Experience,* and *Irrigate Crops*Total Acres* (table 4). Farm managers located in the western part of the state are willing to plant 105.02 more acres then farm managers in the rest of the state. This captures differences in this region of the state due to geography, cultural practices and other unmodeled heterogeneity. A positive relationship with *Total Acres* is expected. As acreage increases, farm managers have a greater ability and incentive to potentially diversify their enterprises. With a greater variability in land quality and available water holding capacity, it may be advantageous to grow an annual bioenergy crop. As farm managers increase their farm size by one hundred acres, they are likely to plant 2.35 more acres of a dedicated annual bioenergy crop. Furthermore, farms with off-farm sources of income would be willing to plant 64.60 more acres and each additional year of experience increases a farm manager's initial acreage by 1.84 acres per year. It could be that farm managers with experience who are willing to plant an annual bioenergy crop may have more experience with new crops than less experienced farm managers and are willing to try them out on a larger area of land. Larger farms with irrigation are likely to plant 2.12 more acres initially for every 100 acres of land than farms that are non-irrigated.

5.3 Dedicated Perennial Bioenergy Crop

The estimation results for farm manager willingness to grow a dedicated perennial bioenergy crop (e.g. switchgrass) are reported in table 3. The unconditional marginal effects indicate that the variables *West*, *Percent CRP*, *Percent Leased* and *Conservation Plan* all effect farm managers' willingness to grow and are statistically significant. Farm managers located in the western part of the state are less likely to plant this type of crop than farm managers in the rest of the state. This could be due to the fact that farm managers in western Kansas receive limited rainfall and they do not experiment as much with other crops given the climate. The dominate crops in western Kansas are corn, soybeans, sorghum, wheat, alfalfa, and hay. Perennial crops, like switchgrass, are potentially viable crops for growing on marginal land, similar to CRP land

(Anand et al., 2011). Managers with larger amounts of acres in CRP may be able to increase their income by growing a perennial bioenergy crop on marginal land rather than leaving it idle or putting it into CRP. Of course, this will be influenced by CRP rental rates. If the CRP policies were changed to allow harvesting of the CRP land for a dedicated perennial bioenergy crop, this could create a value-added production. The marginal effect indicates that if a farm manager increases the percentage of CRP land by 1% the marginal effect of this increase would be that the farm manager is 1.92% more likely to be willing to grow a dedicated perennial bioenergy crop. Farm managers may be more likely to plant a dedicated perennial bioenergy crop if they have more rented land. This result may arise as farm managers may prefer the option of a perennial crop that can help to rebuild the soil on marginal or highly erodible areas on rented land to make it more productive (Sanderson and Adler, 2008), which may potentially help cover the rental costs for the land and make marginally productive areas more productive. In addition, if the farm manager could obtain cheaper rental land, growing a dedicated perennial bioenergy crop may be enticing as production costs, time commitments, and machinery needs may be less (e.g. custom harvesting by the biorefinery). *Conservation Plan* has a positive effect on farm manager willingness to produce a perennial cellulosic biofuel, which is in line with the findings of Jensen et al. (2006).

The unconditional mean initial number of acres to be planted of a perennial bioenergy crop by farm managers who were willing to adopt is 97.0 acres. This matches what was found for a study of landowners in southern lower Michigan (Skevas et al., 2016). The initial allocation of land a farm manager is willing to commit for the production of a perennial bioenergy crop is positively affected by residing in western Kansas (*West*) (table 4). While farm managers on average in western Kansas are less likely to plant a perennial bioenergy crop, those farm managers who are willing to plant, are willing to plant 169.16 more acres than in other parts of the state. However, larger farms in western Kansas are willing to plant 4.14 less acres per 100 acres of land (*West*Total Acres*) than farms located in other regions of the state. For each additional year of experience, a farm manager would initially be willing to plant 2.00 acres per year. Again, this could be due to farm managers having more experience with different crops and their willingness to trial on a larger area.

6. Summary and Conclusions

This paper examines the probability that Kansas farm managers are willing to harvest crop residue and grow dedicated bioenergy crops. Three different types of cellulosic bioenergy crops are considered; harvesting of crop residue like corn stover, a value-added enterprise; a dedicated annual bioenergy crop like energy or sweet sorghum; and a dedicated perennial bioenergy crop like switchgrass. The study data was collected from face-to-face surveys conducted in three regions of Kansas. An expected utility framework is utilized to examine the likelihood farm managers are willing to harvest a crop residue or grow a bioenergy crop. The corresponding empirical model is estimated as a trivariate probit model. For the two bioenergy crop options, an initial acreage allocation model is estimated as well. In order to account for the self-selection bias, the inverse mills ratio is used in estimating the initial acreage allocation model.

The study found that 77% of survey respondents are willing to harvest crop residue, while 61% are willing to grow an annual bioenergy crop; 44% of respondents are willing to grow a perennial bioenergy crop; and 33% of farm managers are willing to grow all three. The survey also reveals that the conditional average amount of land a farm manager is initially willing to devote to growing an annual bioenergy crop is 122 acres, while they are only willing to devote

97 acres to growing a perennial bioenergy crop. Given the goal for cellulosic biofuel production set by the federal government keeps shrinking due to a failure to meet production goals, the results of this study may help in explaining the failure to meet these goals. While farmers may be willing to produce biofuel feedstocks under a favorable contract, other conditions impact their willingness to adopt or industry is not targeting the right types of producers. Furthermore, results indicate that even with adoption, the extent of adoption may be small, precluding the ability of the industry to meet cellulosic goals set by the government at the present time. Biorefineries will have to take into careful consideration the types of cellulosic feedstocks they utilize for producing biofuels. A limitation of this study for determining the potential supply of land for bioenergy production was that prices for the feedstocks examined were not included in the survey question analyzed. Future research, should examine the impact of changes in prices of bioenergy feedstocks on farm managers' willingness to supply land for bioenergy production, especially for dedicated annual bioenergy crops.

Farm managers consider whether to harvest crop residue and dedicated annual bioenergy crop simultaneously as well as the dedicated annual bioenergy crop and the dedicated perennial crop simultaneously. Despite simultaneously considering which feedstock to adopt and the fact that all three feedstocks are cellulosic feedstocks, the factors that have a statistically significant effect on the adoption model and initial acreage allocation model differ depending on the type of feedstock examined. Farm managers in western Kansas are less likely to harvest crop residue or a dedicated perennial bioenergy crop. However, those farm managers who are willing to grow a dedicated annual or perennial bioenergy feedstock are likely to plant more acres than farmers in the rest of the state. In addition, farm managers who lease land are more likely to grow a dedicated annual and perennial bioenergy crop and if farm managers have more experience they are willing to plant more acres of the dedicated annual and perennial bioenergy crops, initially. *Percent Leased* is positive and statistically significant for both the dedicated annual and perennial bioenergy crop decisions. However, this is the only variable that is significant in the decision to adopt both of these biomass feedstock alternatives. In general, despite the correlation between the decisions, a variety of different factors affect the decision to potentially adopt alternative feedstocks by farm managers. In the models that estimate factors affecting the initial acres of bioenergy crop production: *West* and *Experience* are positive and statistically significant in both initial acreage allocation models.

It is believed that having inconsistent results between which variables are statistically significant in all three models is important. These results imply that farm managers view the three different types of cellulosic feedstock differently from one another which means biorefineries must do the same; instead of viewing all potential cellulosic feedstocks as interchangeable. That is, industry may have the goal of developing biorefineries that are "feedstock agnostic" or willing to accept multiple feedstocks, but must recognize that it will have to treat the production of each feedstock differently if contracting directly with farm managers. In moving forward with the production of cellulosic bioenergy facilities, it is important that biorefineries, intermediate processors and industry work with farm managers to negotiate individual contracts based on which type of bioenergy crop the farm manager is willing to produce to help ensure adequate feedstock supply.

6.1 Policy Implications

These results point to some potential implications for polices designed to encourage production of cellulosic biomass in the development of supply for the cellulosic ethanol industry. Potential contracts for farm managers will need to be tailored to the type of bioenergy feedstock desired: crop residue, dedicated annual crop, and/or dedicated perennial crop. Incentives in the form of cost share or subsidies will likely need to be relatively larger for dedicated annual and perennial crop options, given that farm managers are less willing to adopt perennials and annuals bioenergy crops than harvest crop residues. Furthermore, the CRP program rules and incentives would need to be altered to encourage significant acres of perennial crops to be produced and harvested on such land, since currently CRP rules do not allow perennial crops to be harvested at the frequency required for cellulosic feedstock production. Refer to Mapemba, et al. 2007 for additional information concerning producing biomass on CRP. Model results suggest this is an alternative farm managers would support. However, such incentives may be counterproductive to environmental policy designed to protect soil and water resources. Policy requirements to leave adequate amounts of residue on the field to prevent environmental damage may be feasible. Extension education and crop insurance programs designed for dedicated bioenergy crop will likely need to be developed to help managers deal with real or perceived risk of adopting new crops. This suggestion is based on the different factors affecting a farm manager's willingness to adopt. Finally, given the difference in adoption patterns across feedstock types and landscape, flexible and heterogeneous policies that promote feedstock production across crops and regions where farm managers bid in acreage devoted to dedicated bioenergy crop production in crop rotations or as perennials is more likely to have positive results than a homogeneous policy approach.

[1] Production of cellulosic ethanol at Abengoa Bioenergy had not started at the time the survey data was collected. To avoid biasing the results, the survey area did not include the area of Kansas that is currently serving Abengoa Bioenergy. The cellulosic ethanol plant constructed by Abengoa Bioenergy was located in Hugoton, KS. The plant became operational in 2015, but ceased all operations in 2016. The conversion technology was operational and producing, but was not producing at levels of production needed by Abengoa Bioenergy. The facility closed due to financial issues related to the parent company and Abengoa Bioenergy (Lane, 2015).

[2] Irrigate Crops was found to be highly statistically insignificant in the joint adoption model for a dedicated perennial crop and was excluded to improve model performance and fit due to lower degrees of freedom.

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Table 1. Comparison of Kansas and Bordering States Farm Manager Demographics to Survey Respondents

	Survey	2012 Census of Agriculture[a]			
		Kansas	Nebraska	Oklahoma	Colorado
Age (years)[b]	55.1	58.6	56.0	59.8	59.4
Average size of farm (acres)[b]	2172	1553	1760	1520	2092
Average amount of rented land on farm (acres)[b]	1271	1017	990	903	1124
Average amount of owned land on farm (acres)[b]	900	899	1094	898	1503
Average amount of permanent pasture land on farm (acres)[b]	594	702	1201	788	1565
Average market value of agricultural products[c]	$200,000 to $399,999[d]	$448,317	$708,419	$331,251	$500,350

[a] *Source*: USDA, National Agricultural Statistics Service, 2013

[b] 2012 Census of Agricultural descriptive statistics for each state where calculated for farms above 260 acres in size.

[c] 2012 Census of Agricultural descriptive statistics for each state where calculated for farms above 260 acres in size and $50,000 in gross farm sales.

[d] Category represents the one chosen with the highest frequency by respondents.

Table 2. Variable Definitions and Summary Statistics

Variable	Description	Mean (Standard Error)[a] (N=203)
	Dependent Variables	
VA	Equal to "1" if the farm manager would be willing to harvest residue from a value added crop, "0" otherwise	0.77
AC	Equal to "1" if the farm manager would be willing to grow an annual bioenergy crop, "0" otherwise	0.63
ACIA	The initial acreage a farm manager would be willing to plant of an annual bioenergy crop (truncated at 0) (N = 130)	122.24 (142.95)
PC	Equal to "1" if the farm manager would be willing to grow a perennial bioenergy crop, "0" otherwise	0.46
PCIA	The initial acreage a farm manager would be willing to plant of a perennial bioenergy crop (truncated at 0) (N = 95)	97.04 (112.29)
	Farm Characteristics	
West	Equal to "1" if the farm is located in the western region of Kansas, "0" otherwise	0.30
Total Acres	Total number of acres the farm manager operates (00s of acres)	22.12 (17.41)

Percent Leased	Fraction of total acreage that is leased	0.57
		(.31)
Percent CRP	Fraction of total acreage that is enrolled in CRP	0.01
		(.03)
	Farm Practices	
Graze Residue	Equal to "1" if the farm manager grazes the residue, "0" otherwise	0.51
Bale Residue	Equal to "1" if the farm manager bales the residue, "0" otherwise	0.30
Use Baler	Equal to "1" if the farm manager currently uses a baler, "0" otherwise	0.60
Livestock	Equal to "1" if the farm manager owns livestock, "0" otherwise	0.62
Irrigate Crops	Equal to "1" if any crop is irrigated, "0" otherwise	0.35
Conservation Plan	Equal to "1" if the farm has a conservation plan, "0" otherwise	0.82
Rotate Crops	Equal to "1" if the farm manager rotates the crops, "0" otherwise	0.99
CV Till	Equal to "1" if the farm manager uses conservation tillage practices on corn, sorghum and/or wheat, "0" otherwise	0.92

Farm Manager Characteristics		
Off-Farm	Equal to "1" if any member of the household brings home off-farm income, "0" otherwise	0.51
Experience	The number of years the farm manager has operated the farm	34.29 (12.98)
College	Equal to "1" if the farm manager graduated from college, "0" otherwise	0.33
Risk Avoider	Equal to "1" if farm manager avoids taking risks when possible, "0" otherwise.[b]	0.38

[a] Standard Errors are only provided for continuous variants. The standard error for a binary is equal to the square root of *p(1-p)*, where *p* is the mean of the response or probability that the variant is equal to 1.

[b] A question was posed to respondents, asking them how their neighbors would describe their risk taking behavior. A person who was designated as a risk avoider was someone who was "an extreme risk avoider" or "cautious" (two possible answers to the question). The other options were: "willing to take risks after adequate research"; "not really concerned about risk"; "enjoy taking risks in my business"; and "a real gambler".

Table 3: Estimation Results for the Adoption Model of Value-Added, Dedicated Annual Bioenergy Crop, and Dedicated Perennial Bioenergy Crop Feedstocks

Variable	Coefficient Estimates (Standard Errors) for the Trivariate Probit Model[a]			Unconditional Marginal Effects for Each Feedstock Type[a,b]		
	Value-Added	Annual Bioenergy Crop	Perennial Bioenergy Crop	Value-Added	Annual Bioenergy Crop	Perennial Bioenergy Crop
Intercept	1.45	0.80	-1.33**	--	--	--
	(1.00)	(1.29)	(0.64)			
West	-0.81***	-0.071	-0.35	-0.24**	-0.023	-0.13**
	(0.29)	(0.28)	(0.24)	(0.099)	(0.0642)	(0.061)
Percent CRP	--	--	5.29*	--	--	1.92***
			(3.00)			(0.74)
Total Acres	0.010	0.017**	0.0023	0.0023	0.0053**	0.0009
	(0.0072)	(0.0083)	(0.0070)	(0.0019)	(0.0024)	(0.0019)
Percent Leased	-0.076	0.77*	0.76**	-0.020	0.25**	0.28***
	(0.50)	(0.43)	(0.37)	(0.11)	(0.12)	(0.074)
CV Till	-0.84	-0.54	--	-0.17	-0.16	--
	(0.77)	(0.50)		(0.20)	(0.12)	
Graze Residue	0.081	0.47*	0.25	0.021	0.15**	0.090
	(0.34)	(0.27)	(0.24)	(0.085)	(0.078)	(0.068)
Bale Residue	0.28	0.55**	0.19	0.071	0.17**	0.071
	(0.33)	(0.28)	(0.23)	(0.088)	(0.08)	(0.063)

Off-Farm	0.42*	0.39	0.16	0.11	0.13*	0.059
Income	(0.26)	(0.25)	(0.21)	(0.073)	(0.069)	(0.057)
Experience	-0.0033	-0.011	0.0021	-0.0009	-0.0036	0.0008
	(0.011)	(0.010)	(0.0084)	(0.0025)	(0.0024)	(0.0025)
Conservation	0.19	0.17	0.55*	0.051	0.056	0.19***
Plan	(0.34)	(0.35)	(0.29)	(0.085)	(0.082)	(0.071)
Risk Avoider	-0.19	-0.44*	-0.24	-0.050	-0.15**	-0.088
	(0.26)	(0.24)	(0.22)	(0.068)	(0.070)	(0.069)
College	-0.009	0.036	0.16	-0.0022	0.012	0.060
	(0.28)	(0.27)	(0.23)	(0.068)	(0.059)	(0.055)
Livestock	-0.24	-0.15	0.031	-0.060	-0.049	0.011
	(0.31)	(0.27)	(0.25)	(0.078)	(0.063)	(0.061)
Irrigate Crops	0.34	-0.018	--	0.085	-0.0059	--
	(0.25)	(0.25)		(0.068)	(0.058)	
Rotate Crops	--	-0.83	--	--	-0.22	--
		(0.86)			(0.20)	

Correlations	
Value-Added and Annual Bioenergy Crop	0.72***
	(0.10)
Value-Added and Perennial Bioenergy Crop	0.17
	(0.16)
Annual Bioenergy Crop and Perennial Bioenergy Crop	0.51***
	(0.12)
Fit Statistics	
Log likelihood	-313.20
McFadden Pseudo R^2	0.11
AIC	716.40
Number of Observations	203

[a] The asymptotic standard errors are in provided in parentheses. *,**, and *** designate statistical significance at the 10, 5 and 1 percent level, respectively.

[b] Unconditional marginal effects represent the marginal effects of adopting an individual feedstock independently of the other feedstocks. The use of the trivariate probit model for estimation corrects for any correlation between the choices. All marginal effects are calculated at the mean of the explanatory variables.

Table 4. Estimation Results of Initial Acreage Allocation Models for Annual and Perennial Crop of Potential Farm Manager Adopters

Variable	Annual Crop Initial Acres		Perennial Crop Initial Acres	
	Coefficient	Standard Errors	Coefficient	Standard Errors
Intercept	-67.55	112.83	-87.83	104.72
West	105.02**	46.94	169.16***	46.03
Percent CRP	---	---	263.05	439.45
Total Acres	2.35*	1.31	2.57	1.60
Percent Leased	68.20	42.58	41.38	50.51
Use Baler	-27.06	28.19	-15.79	26.22
Off-Farm	64.60**	28.60	-13.29	26.83
Experience	1.84*	1.01	2.00*	1.07
CV Till	-36.85	40.30	---	---
Risk Avoider	24.42	29.30	32.90	26.79
Irrigate Crops	-1.31	40.04	39.84	41.09
Rotate Crops	-30.84	91.89	---	---
Graze Residue	---	---	-28.17	39.66

West * Total Acres	-1.15	1.34	-4.14***	1.35
Irrigate * Total Acres	2.12*	1.23	0.29	1.37
Graze Residue * Total Acres	---	---	0.23	1.42
Inverse Mills Ratio Annual Crop	54.59	67.74	---	---
Inverse Mills Ratio Perennial Crop	---	---	31.28	83.94
Fit Statistics				
R-Squared		0.24		0.24
Observations		130		95

Note: * denotes statistical significance at the 10% level, ** denotes statistical significance at the 5% level, and *** denotes statistical significance at the 1% level.

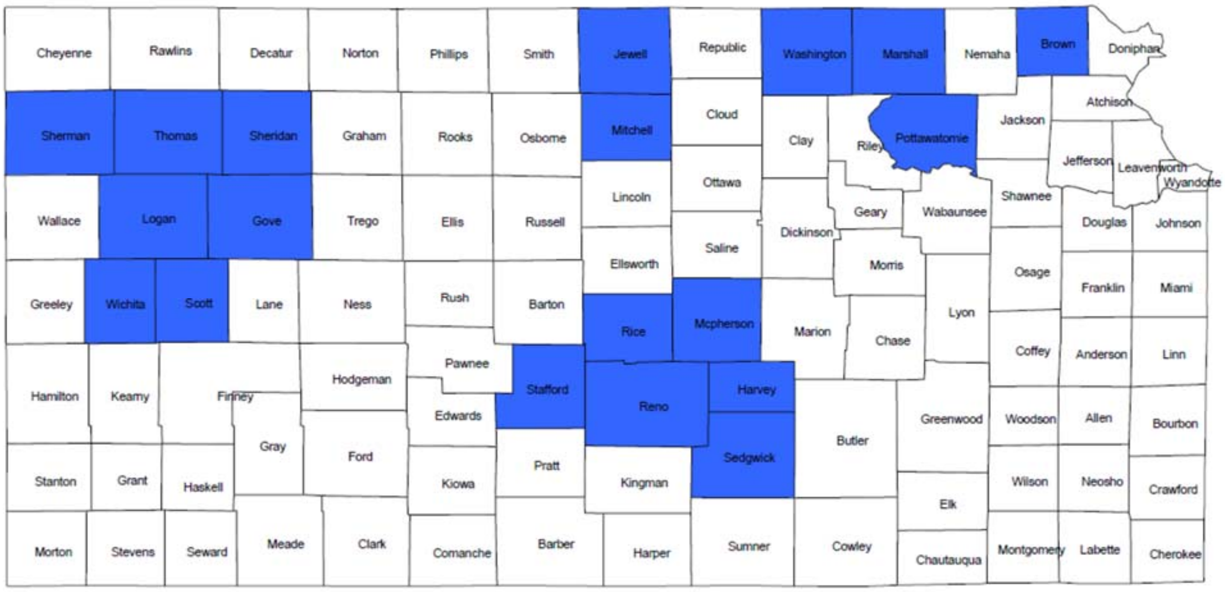

Figure 1. Map of Surveyed Counties in Kansas

In the following table, indicate if you would be willing to produce the following types of biofuel feedstocks and how much you would be willing to harvest/plant of that feedstock.

Cellulosic Biofuel Feedstock Type	**Considering you enter into a favorable contract with a refinery, would you produce this biofuel feedstock on your farm?** (*Choose one*)	**If Yes, what is the minimum acreage you would initially be willing to plant of this bioenergy crop/feedstock?** (*Assume the crop can be planted on rented lands*)
a. Value Added (e.g. crop residue, such as corn stover, wheat straw, etc.)	___ Yes ___ No	
b. Annual Crop (e.g. sweet sorghum)	___ Yes ___ No	
c. Perennial (e.g. switchgrass, miscanthus, prairie grasses, etc.)	___ Yes ___ No	

Figure 2. Survey Questions Asking Farm managers to Indicate Whether They Would be Willing to Produce a Bioenergy Crop Under Favorable Contracting Situations, and If So, How Many Acres They Would Commit to Grow Initially