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Factors affecting willingness to cultivate switchgrass: Evidence from a farmer survey in Missouri

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ABSTRACT

Switchgrass is considered as one of the important feedstocks that can contribute towards the attainment of bioenergy goals set under the Renewable Fuels Standard. Yet, the commercial viability of switchgrass based bioenergy is a much debated topic owing to supply side challenges emanating from limited raw materials. It is therefore critical to understand the crucial role of the farmer by studying the willingness to cultivate switchgrass dedicated for bioenergy. To our knowledge, this is the first survey undertaken to assess the farmer preferences and participation in bioenergy markets after the new administration has assumed office, and provides some important insights. Our analysis reveals that the risk attitudes of farmers have an important bearing on their willingness to cultivate switchgrass. Having prior awareness of switchgrass makes farmers less likely to adopt whereas a preference to cultivate a crop after seeing them on demonstration plots at university extension meetings positively influences willingness decisions. Landholdings under pasture/grazing use and under forest/woodland use increases farmer willingness to cultivate switchgrass. On the other hand, having land under the Conservation Reserve Program, lands that experienced flooding or water stress in recent years, or lands that confront erosion issues did not have a significant influence on farmer willingness. While the inherent uncertainty of the cellulosic bioenergy industry is well known, policies that provide a safety net to protect farmers from the downside are an important issue for farmers who are willing to cultivate switchgrass.

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1. Introduction

The United States (U.S.) government, through policies such as the 2007 Energy Independence and Security Act (EISA) increased the renewable fuel standards (RFS) target to 36 billion gallons (approximately 136 billion liters) by 2022, while capping the contribution of corn-based ethanol to 15 billion gallons (approximately 57 billion liters). The remaining 21 billion gallons (approximately 79 billion liters) would constitute cellulosic ethanol and other advanced biofuels. While these targets have since been revised on multiple occasions, owing to a host of factors, emphasis on the need to develop alternate energy sources remains an important aspect of U.S. energy policy.

Cellulosic biomass feedstocks, including switchgrass and other energy grasses, are expected to become key sources of raw material for biofuel production. On the one hand, feedstocks such as switchgrass partially obviate the food vs. fuel debate surrounding biofuel production (Bardhan and Jose, 2012; Weerasekara et al., 2018). On the other hand, switchgrass has been identified as a high potential bioenergy feedstock given its high biomass yield and ethanol conversion potential, among other factors (Wright, 2007). It is native to the U.S., has a deep-root system that helps with erosion control and substantial below-ground carbon sequestration, requires limited use of fertilizers, and can serve as a wildlife habitat. Switchgrass, other energy grasses, and woody feedstocks also provide a suitable opportunity to diversity the feedstock mix away from an over reliance on corn-based ethanol. Additionally, switchgrass can be used for co-firing with coal to produce electricity (Rasnake et al., 2013).

Multiple factors have held back the commercial deployment of cellulosic biofuels so far, including slower than anticipated technological advancements in the conversion processes associated with producing fuels from cellulosic biomass, improved fuel efficiency which lowers demand for ethanol, capital constraints, etc. However, one of the major obstacles associated with large-scale development of cellulosic biofuels

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pertains to the uncertainty in the price of the feedstock and a lack of assured year-round feedstock supply (Uden et al., 2013; Dumortier et al., 2017). Additionally, the unpredictability of fuel markets and its impact on costs and revenues from biofuel production, uncertainty in the policy environment, and irreversibility of investment actions has hindered market entry (Schmit et al., 2011; McCarty and Sesmero, 2015; Markel et al., 2018). The challenges faced by the cellulosic bioenergy industry are often described as a chicken and egg problem, where adequate investment and infrastructure for feedstock conversion is not forthcoming owing to a lack of assured feedstock supply and farmers are unwilling to cultivate dedicate bioenergy feedstocks until a steady market is established and adequate demand is created (Luo and Miller, 2017). While existing literature often assumes 100% participation in supplying feedstocks, experience indicates lower participation rates and supplier heterogeneity pertaining to willingness to supply biomass (Li et al., 2018). As a result, understanding farmer preferences and the underlying factors that inform their decisions is paramount to evaluate the supply side bottlenecks in the bioenergy industry.

Earlier studies have analyzed the factors that influence farmer willingness to grow feedstocks for biofuel production. While the benefits associated with switchgrass including erosion control, wildlife habitat, soil conservation, improvements in water quality, etc. are likely to encourage cultivation; factors such as lack of information, long establishment periods, and absence of a reliable markets for the feedstock are crucial impediments (Hipple and Duffy, 2002). Jensen et al. (2007) conducted a survey of farmers in Tennessee to evaluate their willingness to supply switchgrass. They found that a majority of respondents had not even heard of growing switchgrass for energy production and identified lower age, higher education, and off-farm income as factors that positively influenced willingness to cultivate switchgrass while farm size, higher farm incomes and use of leased farmland had a negative influence on share of farmland likely to be converted to switchgrass. Additionally, other factors such as erosion problems, desire to provide wildlife habitat, views about on-farm issues, and national policy issues were also studied in their research (Jensen et al., 2007).

Given the relatively long establishment period for switchgrass, and the time lag between planting and harvesting the feedstock, investments in switchgrass tend to be impacted by various types of risks including biophysical, financial, climatic, and policy uncertainty. Therefore, investments in perennial bioenergy crops are often considered to be more risky than other bioenergy feedstocks (Pannell et al., 2006; Song et al., 2011). In addition to liquidity and investment reversibility constraints, farm level risks and intertemporal fluctuations in income also influence farmer decisions pertaining to perennial energy crops (Bocqueho and Jacquet, 2010; Bocquého, 2017). Meanwhile, Bergtold et al. (2014) assessed farmers' willingness to produce cellulosic feedstocks under contractual arrangements. The authors adopted stated choice experiments and a random utility model framework to examine farmer decisions to find that contract length, cost share, financial incentives, insurance, custom harvest options, and net returns above the next best alternative land use are important attributes that could influence choices.

Using a survey of farmers in 12 southern states of the US, Qualls et al. (2012) delineated that factors such as farm size, raising beef cattle, age, location, concern about having the necessary financial resources and equipment negatively influenced interest in cultivating switchgrass. On the other hand, ownership of hay equipment and the possibility of lowering fertilizer and herbicide applications led to higher likelihood of interest in cultivating switchgrass. Their research found that the above-mentioned factors also influenced the share of land farm managers were willing to convert to switchgrass cultivation. Lynes et al. (2016) examined farmer willingness to harvest crop residue, grow a dedicated annual or perennial bioenergy feedstock in Kansas. They found that only 44% of the respondents were willing to grow a perennial bioenergy crop, and were willing to devote, on average, 39.25 ha for this purpose. The location of the farms, percentage of land under the conservation reserve program (CRP), and proportion of leased farmland were significant variables that explained farmer willingness. Furthermore, farm managers who had conservation plans were also more likely to produce perennial cellulosic feedstocks.

Research from other countries and varied types of cellulosic feedstock also identify a similar set of factors that can potentially influence farmer or landowner willingness to cultivate feedstocks. An analysis of Swedish farmers by Paulrud and Laitila (2010) identified age of the farmer, size of the farm, and geographical area as significant characteristics that may influence the willingness to grow bioenergy crops. Furthermore, opportunity costs associated with committing land to perennial energy crops, reversibility of decisions and returning the land to other uses, policy environment appear to be some of the barriers to adoption in the U.K. (Sherrington et al., 2008). Factors such as off-farm labor, land size, and farmer education were important determinants of adoption of energy crops on farms in Spain (Giannoccaro and Berbel, 2012). Finally, for woody bioenergy feedstocks such as pine, price, preference for producing non-timber products, and lower dependence on the land for income resulted in higher likelihood of forestland allocation for growing dedicated bioenergy feedstocks (Wolde et al., 2016). Villamil et al. (2008) studied farmers' informational needs pertaining to miscanthus adoption in Illinois and found low levels of awareness about the crop and substantial regional divergence in terms of willingness to cultivate. They also identified heterogeneous preferences for information and the channels through which information was accessed by the farmers.

Together these studies provide useful insights on some of the most important issues around the cultivation of switchgrass, and other feedstocks, for bioenergy. We build on these studies and extend the research by analyzing farmer willingness to grow switchgrass in the state of Missouri. Our study examines the influence farmer risk attitudes, prior awareness of switchgrass, and importance placed on information gained from university extension meetings or other farmers. In addition, we evaluate a broader set of variables pertaining to the land including type of land holding, experience of water stress, flooding, or erosion on the land, as well as socioeconomic characteristics using rigorous analytical frameworks. The study also highlights the role of policies for encouraging the cultivation of switchgrass.

2. Study area

2.1. Data and survey design

Agriculture is an important contributor to Missouri's economy. A report by the Missouri Department of Agriculture highlights that the state ranked second in the number of farm operations with over 99,000 farms and is one of the leading producers of grain and oilseeds in the United States (USDA, 2014; Missouri Department of Agriculture, 2016). Further, the state ranked 12th in ethanol production and is a major player in the bioenergy sector in the country. Missouri is placed second in the US in terms of the area under cultivation for forage land at 1.35 million hectares and fourth for soybeans with over 2 million hectares under cultivation and also ranks high on the list of states producing corn, wheat, and livestock (USDA, 2014).

To our knowledge this was the first survey evaluating the perceptions of the farming community pertaining to bioenergy markets after the new administration assumed office in January 2017. A database of 5000 farmer addresses in Missouri was obtained from ListGiant, a company that provides targeted mailing lists. We randomly selected a sample of 1000 farmers from aforementioned list to participate in the study and mailed them a survey in the month of March and April 2017. As we did not have reliable metrics such as those based on farm size or minimum value of agricultural sales, we did not use any exclusion restrictions in our sample selection procedure as used in previous studies (Jensen et al., 2007; Qualls et al., 2012). The survey packet included a cover letter, forms seeking the respondent's consent to utilize their data for the survey, a copy of the survey, and a self-addressed postage-paid return envelope.

The survey instrument contained a brief background about switchgrass and its use as a bioenergy feedstock and 33 questions spanning (i) farm size, characteristics, and current farming practices; (ii) knowledge of and interest in cultivating switchgrass; (iii) price requirements and potential land that would be devoted to switchgrass under favorable conditions; (iv) opinions about cultivation decisions, environment, society, and policies; (v) individual characteristics and demographic attributes of the respondents. We analyzed farmer willingness to cultivate switchgrass and evaluated their responses pertaining to the importance of specific policies that could support the cultivation of switchgrass.

The initial mailing was followed by a reminder postcard a week later. About 3 weeks later, a second survey packet was mailed out to non-respondents. The follow-up mailing also included a cover letter urging the recipients to participate in the survey, consent forms, a copy of the survey questionnaire, and a self-addressed postage-paid return envelope.

2.2. Survey responses

Out of the 1000 surveys mailed, 72 were returned as undeliverable due to incorrect addresses. 115 respondents indicated that they were unwilling to participate in the survey by sending a return note or a blank survey. 135 respondents completed the survey. Based on the above, the survey response rate was 14.5%. Out of the 135 respondents who completed the survey, 105 responses were usable for performing our analysis examining farmer willingness in response to farm-level characteristics, risk preferences, information and demographic attributes. For our analysis pertaining to the importance of specific policy variables, we had 100 complete responses. The lower number of responses is owing to the fact that not all respondents answered all the questions, and we have considered only the most complete responses. Similar approaches have been used in previously published literature (Jensen et al., 2007; Qualls et al., 2012; Lynes et al., 2016).

A comparison with the 2012 Agricultural Census for Missouri published by the United States Department of Agriculture (USDA, 2014) highlights the following similarities and differences compared to our research sample. A majority of the farmers in the state of Missouri report their ethnicity as white or Caucasian with 97.3% of all farmers representing this ethnic category. In our survey sample, the proportion of respondents reporting their ethnicity as Caucasian was 99.0%. While proportion of male and female principal farm operators in Missouri is 88.8% and 11.2% respectively, our research sample had 86.7% male respondents and a marginally higher representation of female farmers with 13.3% female respondents. In terms of land holdings, the average farm size in Missouri is 115.33 ha whereas the average farm size for our survey sample came in at 84.33 ha. The distribution of survey respondents by farm size is provided in Table 1.

Compared to the statewide data, we received a higher response from farmers in the 3.65–19.83 ha category, and a somewhat lower response from farmers in the 19.84–72.44 ha category. The distributions in the other categories are fairly in line with the 2012 Missouri Agricultural census data. With regard to the age of the survey respondents, our sample had the highest number of responses, 54.3%, for the above 60 years age category followed by 23.8% in the 51–60 years category. The other age categories <30 years, 31–40 years, and 41–50 years had 1.0%, 6.7% and 13.3% respondents respectively. Data was missing for one respondent. The distribution of respondent age is similar to the age distribution of farmers in the state of Missouri, although the specific age categories are slightly different. For example, according to the 2012 Missouri Agricultural census data for farming and other operations 0.6% of operators were <25 years, 5.7% (25–34 years), 10.3% (35–44 years), 22.2% (45–54 years), 27.3% (55–64 years) and 33.9% were over 65 years in age. The average age of the principal operator in Missouri in 2012 was 58.3 years. A closer examination of operators primarily engaged in farming revealed that 0.7% of operators were <25 years, 4.7% (25–34 years), 7.3% (35–44 years), 16.4% (45–54 years), 26.0% (55–64 years) and 44.9% were over 65 years in age.

Table 1
Comparison of land holdings by respondents.

Hectares	Proportional land holdings in Missouri	Proportional land holdings in survey sample
0.40–3.64	3.6%	3.8%
3.65–19.83	21.9%	39.0%
19.84–72.44	37.3%	25.7%
72.45–201.94	23.5%	21.9%
201.95 or more	13.7%	9.5%

Source: USDA Agricultural Census 2014 and survey data represented in SI units.

Finally, our survey responses arrived in three waves following from our initial mailings of the survey, a reminder postcard sent one week after the initial mailing, and a second mailing about three weeks later. We evaluated variables such as size of land holding as well as demographic characteristics such as gender, age, education for the survey respondents' based on the time their responses were received and did not find statistically significant differences in the respondents.

3. Analytical framework

3.1. Logistic regression

The dependent variable (Y) for this analysis is farmer "willingness to cultivate switchgrass", which is binomial in nature. Thus, we use logistic regression to analyze our data. In a logistic regression, the model estimates the probability of a "yes" response occurring given the values of the independent variables (Xs) (Wooldridge, 2015). The probability of willingness to cultivate switchgrass, $P(Y)$, can be expressed as

$$P(Y) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n)}}$$

For our analysis, the Xs represent the various variables in classified as farm characteristics, risk, and demographic variables. The logit model ensures that the probabilities are always between 0 and 1, and the link function $G(z)$, where z is the composite index of all the explanatory variables, has a cumulative distribution function (CDF) given by $G(z) = \frac{e^z}{1+e^z}$ (Agresti, 2003; Greene, 2003).

3.2. Weighting survey responses

Assigning weights to survey responses is a technique used for survey data analysis to ensure that the survey data is representative of the population being studied and common issues such as non-response can be adequately addressed (Kalton and Flores-Cervantes, 2003). Using survey weights is considered an important element for arriving at population estimates and regression parameters that are not just valid for the sample data alone (Valliant et al., 2013). However, as regression models are primarily used to unravel relationships between the dependent and independent variables, it is argued that it should be possible to arrive at these estimates without the use of sampling weights (Lumley, 2011). Overall, one must proceed with caution when using sample weights in the analysis of survey data as weighting tends to make estimates less efficient. A conservative approach is to compare results from both analyses and if the results are similar, the unweighted analysis could be favored from an efficiency perspective for associational parameters whereas weighted estimates could be used for population-level parameters (Platt and Harper, 2013).

Adjustments for non-response can be accomplished through simple tabulation of responses and creating classes with different weights or employing more sophisticated techniques, which require information or assumptions pertaining to the marginal distributions of the variables and interactions (Kalton and Flores-Cervantes, 2003; Valliant et al., 2013). For our survey, the respondent characteristics are a good representation of the population of farmers in Missouri on several key variables including gender, ethnicity and age as described in Section 2.2 above. However, our sample has a higher representation of individuals with smaller land holdings. We assign proportional weights to the survey responses using the distribution of land holdings from the 2012 Missouri Agriculture Census in order to make our survey sample more representative and correct for any non-response bias that may be present in the data owing to lower responses from farmers with larger land holdings. Respondents in land-holding categories that were overrepresented in our sample received a weight <1, whereas underrepresented categories received a weight >1. We compared results from the weighted and unweighted regressions.

3.3. Transformation of variables and recursive partitioning

Some of the variables pertaining to land characteristics had skewed distributions. A usual method of dealing with skewed distributions with positive values is to consider logarithmic transformations of the variables. While this method was suitable for the land holding variable 'hectares', the other variables which depicted land holdings in specific land use categories such as cropland, grazing land, woodland or non-agricultural land had several 'zero' values. In order to transform these variables for our analysis we utilized the Box-Cox transformations wherein the variable is transformed as

$$g(x;\lambda_1,\lambda_2)=\frac{(x+\lambda_2)^{\lambda_1}-1}{\lambda_1}\ \text{when}\ \lambda_1\neq 0$$

and

$$g(x;\lambda_1,\lambda_2)=\log(x+\lambda_2)\ \text{when}\ \lambda_1=0$$

A common choice in the two-parameter version is to have $\lambda_1 = 0$ and $\lambda_2 = 1$, a convenient property of which is that it maps the zeros to zero (Hyndman and Grunwald, 2000; Hyndman, 2010). We anticipated that a log-transformation of these continuous variables would best capture the relationship between farmer willingness and the land holding under various types of land use and log-transformations would also correct for the skewness in the distribution of the data. We also allowed the estimation procedure to determine the values for λ_1 and λ_2 in the transformations using the 'geoR' package in R (Ribeiro and Diggle, 2007). Our results and interpretations of the variables were similar.

Recursive partitioning is a technique used to split data into categories, wherein observations that belong to the same group exhibit similar characteristics (Strobl et al., 2009). It is an exploratory tool that can be used to identify thresholds and delineate clusters that indicate statistical differences in response variables vis-à-vis the independent variable when evaluated using a *t*-test (Lal et al., 2016). Similar approaches have been applied in a variety of fields including medicine, finance, and conservation (Betts et al., 2007; Daubie et al., 2002; Strobl et al., 2009). We utilize this approach to partition some of the variables in the risk and demography categories as we anticipated responses to vary depending on specific thresholds. Dividing the respondents into specific categories based on their responses to questions with Likert-scale responses allows us to study their statistical significance on the dependent variable. Similarly, demographic variables that solicited responses based on some interval scale are classified into optimal clusters for enhancing their predictive capabilities within the model framework. The recursive partitioning analysis performed using the 'rpart' package in R (Therneau et al., 2010), whereby we were able to categorize the responses into groups in which respondents exhibited similar behavior within the group and different behavior across groups. Based on the results of the recursive partitioning analysis, categorical/dummy variables were created to appropriately represent the specific categories. These variables were used as the independent variables in the logistic regression.

3.4. Odds ratio

Odds ratio is extremely important to interpret the coefficients of the logistic regression. The ratio expressed as the probability of success over the probability of failure indicates the resulting change in odds due to a one-unit change in the predictor (Field et al., 2012). The odds ratio is expressed as

$$odds=\frac{P(Y)}{1-P(Y)}$$

and is equivalent to the exponential of the β coefficients from the logistic regression. In case of non-linear transformations of the independent variables, the interpretability of the odds-ratio is not straightforward (Hosmer Jr et al., 2013). While the odds ratios indicate the direction of influence on the odds of classification, we also include the average marginal effects for the significant variables in the model using analysis performed in the 'margins' package in R (Leeper, 2017).

4. Variable descriptions and hypothesized effects

Previous studies have shown that land size and land use pattern tend to influence decisions pertaining to adoption of biofuel feedstock cultivation (Jensen et al., 2007). We hypothesized that the size of land holding has a positive influence on the decision to adopt switchgrass, as farmers may be more likely to plant switchgrass on part of their land to benefit from the upcoming market opportunities. We used logarithmic transformations for the landholding variables to evaluate their influence on willingness to cultivate switchgrass. The transformed variables have the prefix 'L_' in Table 2.

Since land under crop cultivation is unlikely to be diverted for switchgrass cultivation, we hypothesized that the variable would likely have a negative influence on the farmers' adoption decision. Furthermore, as switchgrass can be considered a close substitute for hay as well as being well suited for agroforestry, we hypothesized that landholding in grazing land and woodland would positively influence farmer willingness decisions. However, it is possible that landholdings, either cumulative or in grazing land and woodland, could have a negative influence on farmer willingness to cultivate switchgrass as the market for such energy crops is not well-developed and farmers could be reluctant to plant switchgrass.

Switchgrass is known to grow well in nutrient deficient systems, so it is possible that land that is considered marginal for traditional row crops or left uncultivated as it is prone to flooding/arid conditions could be diverted to cultivate switchgrass. Similarly, lands that are prone to soil erosion can be planted with switchgrass as its deep-root system can help reduce erosion problems. In addition, the USDA's CRP pays a yearly rental payment to farmers for removing environmentally sensitive land from agricultural production. Such land can be planted with switchgrass, which can help enhance the environmental quality of the soil. We hypothesized that farmers who experienced flooding or drought-like conditions on their farmland, have land under the CRP program, and farmers facing erosion problems on their lands would all be more willing to consider planting switchgrass.

In order to gauge attitudes towards risk, respondents were provided with a statement and were asked to indicate their level of agreement. The statement presented to the respondent was "I am willing to take risks in farming if there is a possibility of earning high profits" and a 5-point Likert-scale schematic wherein a score of 1 indicates strong disagreement whereas a score of 5 indicates strong agreement was provided. Respondents selecting 'Agree' or 'Strongly Agree' to the

Table 2
Variable descriptions and hypothesized effects.

Variable	Description	Variable type	Hypothesized effect
Land characteristics			
L_hectares	Total land holdings	Continuous	(+)/(−)
L_hectares.cropland	Land holdings in cropland	Continuous	(−)
L_hectares.grazing	Land holdings in grazing land	Continuous	(+)/(−)
L_hectares.woodland	Land holdings in woodland	Continuous	(+)/(−)
flood	Respondent states that they experienced flooding on land during the past 5 years	Factor 0: No 1: Yes	(+)
drought	Respondent states that they experienced water shortage/drought-like conditions on land during the past 5 years	Factor 0: No 1: Yes	(+)
crp	Respondent has land holdings under the Conservation Reserve Program (CRP)	Factor 0: No 1: Yes	(+)
erosion	Respondent experiences soil erosion problems on land	Factor 0: No 1: Yes	(+)
Risk and information			
risk	Respondent states that they are willing to take risks in farming if there is a possibility of earning high profits	Ordinal 1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	(+)
univ.ext	Respondent states that they prefer to adopt new crops after seeing them on demonstration plots at University Extension meetings	Ordinal 1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	(+)/(−)
follow.others	Respondent states that they prefer to adopt new crops after seeing them adopted by other farmers	Ordinal 1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	(+)/(−)
awareness	Respondent states that they were aware of switchgrass prior to the survey	Factor 0: No 1: Yes	(−)
Demographic characteristics			
gender	Gender of the respondent	Factor 0: Female 1: Male	(+)
education	Level of education attained by respondent	Ordinal 1: <Middle school 2: High school 3: Some college 4: College graduate or above	(+)
residence.property	Respondents indicate whether their primary residence is on the farm	Factor 0: Not on property 1: On property	(+)

statement were considered to have a higher risk-taking propensity. The responses and corresponding proportions are presented in Table 3.

The recursive partitioning analysis also resulted in a grouping of the responses into two categories, namely those who indicated agreement with the statement and those who were neutral or indicated disagreement. In the analysis, the variable 'risk' was used as a 2-level factor variable. Given that the cellulosic bioenergy industry is still in its nascent stages of development, investments in switchgrass are considered relatively riskier than traditional choices.

For the variables 'univ.ext' and 'follow.others' the survey asked for responses to the statements "I prefer to adopt new crops after seeing them on demonstration plots at University Extension meetings" and "I prefer to adopt new crops after seeing them adopted by other farmers" respectively. In this case too, the recursive partitioning approach clustered the responses in to two distinct categories with one category comprising of respondents who agreed with the statements whereas the other category comprising respondents who were neutral or showed disagreement with the statements.

However, the interpretation of the effects of the two variables is more nuanced. On the one hand, a preference to adopt new crops only after seeing them at demonstrations by university extension services or other farmers indicates some level of risk aversion or a reluctance to be an early adopter. On the other hand, agreement with the statements could also indicate that the respondents prefer to have more information to be better equipped at making a farming decision, even if the decision may entail risks that are relatively larger than their traditional cultivation choices. To that effect, the influence of university extension services and local social networks with other farmers could also influence farmer cultivation decisions. While risk aversion could have a negative influence on farmer willingness to adopt switchgrass, attending university extension meetings to gather new information and seeing others adopt switchgrass could have a positive influence on cultivation choices.

Table 3
Proportional distribution of responses for risk and information related variables.

Statement	Levels	1	2	3	4	5
I am willing to take risks in farming if there is a possibility of earning high profits	1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	5.71%	7.62%	36.19%	42.86%	7.62%
I prefer to adopt new crops after seeing them on demonstration plots at University Extension meetings	1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	6.67%	7.62%	54.28%	24.76%	6.67%
I prefer to adopt new crops after seeing them adopted by other farmers	1: Strongly disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly agree	7.62%	9.52%	46.67%	29.52%	6.67%

While the survey document contained some information about switchgrass, its potential as a bioenergy feedstock, and associated ecosystem services benefits, respondents were asked whether or not they were aware of switchgrass before taking the survey. We hypothesized that the farmers who were aware of switchgrass could likely be less willing to cultivate owing to the long establishment period for switchgrass and the uncertainties associated with price and demand for the feedstock at this point.

Several studies have tried to explore differences in male and female behavior for a variety of research questions. Doss and Morris (2000) investigated whether men and women tend to adopt agricultural innovations at different rates as they felt that if such differences indeed exist it might be necessary to design research and policies that meet their specific needs. In our context, gender can play a role in influencing a farmer's willingness to cultivate switchgrass if men and women have intrinsically different preferences. As men and women tend to demonstrate varied risk assessments, we hypothesized that men could be more willing to cultivate switchgrass for bioenergy.

The variable for education was recursively partitioned into two groups namely respondents educated up to high school or less and respondents with some college education or college graduates. We anticipated that such a classification would allow us to unravel any relationships between switchgrass willingness and educational levels. Previous studies have found that educational attainment has a positive effect on farmer willingness (Jensen et al., 2007; Kelsey and Franke, 2009), and we hypothesized that education would positively influence farmer willingness to adopt switchgrass.

Finally, we included a variable that demonstrated whether the respondent's residence was on the farmland itself. Wolde et al. (2016) studying the willingness to allocate non-forested land for pine plantation found that individuals with a primary residence on their forested property were more willing to adopt a bioenergy feedstock. Having their primary residence on the farmland could indicate more active involvement in farming or on-farm decisions than if the individuals were living elsewhere. We hypothesized that the variable ‘residence. property’ would positively influence farmer willingness to cultivate switchgrass.

5. Results and discussion

In our survey sample, 54.3% of the respondents indicated that they were unwilling to cultivate switchgrass and 45.7% indicated they were willing. Using a univariate analysis, we were able to evaluate our theoretical hypotheses and understand the relationship between our explanatory variables and the dependent variable ‘willingness to cultivate switchgrass’. Many of the results were in line with our prior hypothesis in terms of direction of the influence of the independent variable on the willingness to cultivate switchgrass. Out of the fifteen variables considered for the analysis, the univariate analysis indicated that ten variables had a statistically significant influence on the dependent variable. However, the coefficients in these regressions may not be very useful as univariate regression models are often affected by omitted variable bias. Consequently, we extend our logistic regression model to evaluate a broader set of variables described above. Since the overall land holdings correlated with land holdings under different land uses, we excluded the variable representing the overall land holdings ‘L_hectares’ from the multivariate logistic regression analysis to avoid potential multicollinearity. Our model returns a pseudo-R^2 value of 0.38 and correctly classifies 78% of the observations indicating a reasonably good fit and prediction performance. The proportion of correctly classified observations was 77.2% for respondents unwilling to cultivate switchgrass and 79.2% for respondents willing to cultivate. Table 4 shows results from the multivariate logistic analyses. We found that that the results of the weighted and unweighted regressions are quite similar and our analysis based on the DuMouchel-Duncan test indicated that using sample weights was not needed for this model. As a result, while we report results from both weighted and unweighted regressions, we discuss the coefficients of the unweighted regression, as these estimates are known to be more efficient (Platt and Harper, 2013).

Table 4
Estimation results for the willingness model using multivariate logistic regressions.

Variable	Coefficients and standard errors (unweighted)	Coefficients and standard errors (weighted)
L_hectares.cropland	−0.058 (0.197)	0.012 (0.188)
L_hectares.grazing	0.423** (0.213)	0.400* (0.213)
L_hectares.woodland	0.423* (0.222)	0.472** (0.223)
flood	−0.553 (0.771)	−0.533 (0.736)
drought	−0.175 (0.615)	−0.329 (0.653)
crp	0.493 (0.728)	0.573 (0.720)
erosion	0.425 (0.627)	−0.060 (0.655)
risk	1.976*** (0.688)	1.963** (0.758)
univ.ext	1.301* (0.720)	1.411* (0.758)
follow.others	0.594 (0.632)	0.644 (0.670)
awareness	−1.245* (0.684)	−1.246* (0.725)
gender	1.826 (1.191)	1.389 (1.080)
education	−0.828 (0.734)	−0.968 (0.741)
residence.property	0.166 (0.740)	0.349 (0.808)
constant	−4.002*** (1.545)	−3.564** (1.497)
Observations	105	105
Pseudo R^2	0.377	0.368

Signif. codes:
*** 0.01.
** 0.05.
* 0.1.

The coefficients for land use related variables pertaining to land holding in grazing land and woodland were positive and significant, in line with our expectations. However, we did not find evidence to support our hypothesis that the coefficient for land use under crop production would be negative. The coefficient for this variable was not statistically significant. Land holdings are important for determining farmer willingness for producing bioenergy feedstocks, yet the evidence is not conclusive. While Jensen et al. (2007), found that size of land holdings had a negative influence on farmer willingness, Lynes et al. (2016) found total acres farmed to have a positive and significant influence for willingness to adopt annual bioenergy crops. However, in our analysis, we do not restrict our focus on overall size of farmland but rather on the specific type of land use.

Of the other variables related to the land characteristics, particularly whether the respondent had experience flooding or drought like conditions on their land during the previous five years were not statistically significant. It is possible that farmers might be unsure about the ability of switchgrass to thrive in such situations. Similarly, we did not find evidence to support our hypotheses that farmers with land under the CRP and farmland faced with erosion problems would be more likely to indicate willingness to cultivate switchgrass. Our result pertaining to holdings in CRP land is similar to that of Qualls et al. (2012), who also did not find a statistically significant relationship between interest in growing switchgrass and whether farmers had land enrolled under the CRP program. This result could be influenced by the lack of uniform policies about cultivation and harvest of switchgrass on CRP lands, and may indicate the need to rethink incentives for making the cultivation of perennial energy crops on these lands a more favorable option.

The relationship between farmer willingness and their attitude towards risk was both positive and significant. This result supports our hypothesis suggesting that farmers with higher willingness to take on risks would be more likely to indicate willingness to cultivate switchgrass. This aspect of farmer willingness has been highlighted as important, yet an inadequately researched area. Our results lend support to the hypothesis pertaining to riskiness of investments in bioenergy feedstock cultivation. While Lynes et al. (2016) did not find evidence for a statistically significant relationship between adoption of perennial bioenergy crops; their study confirmed a negative and significant relationship between a farmer's risk aversion and willingness to adopt annual bioenergy crops. Meanwhile, Fewell et al. (2016) found that crop insurance and cost-share assistance were important factors that increased the likelihood of willingness to grow switchgrass in Kansas.

In the case of the variables pertaining to first seeing switchgrass being grown on university extension demonstration plots or other farmers, this variable suggests that farmers who prefer additional information regarding the crop and are more likely to indicate willingness. This result highlights a role for engagement of university extension services in wider dissemination of information pertaining to switchgrass and the value for demonstrations and exhibitions of successful switchgrass establishment.

Additionally, while we hypothesized that local farmer networks could also play an important role for information sharing, we did not find evidence to support this hypothesis. Finally, prior awareness of switchgrass has a negative and statistically significant influence on farmer willingness to cultivate switchgrass. This result suggests that farmers might have the perception that switchgrass is unlikely to be profitable and may not be a viable alternative. Furthermore, they might be concerned about the long establishment period and limited cash flows in the early years of cultivation. As a result, more specific information about farmer concerns and perceptions of switchgrass cultivation should be collected to address their concerns. Our result is different when compared to the study by Jensen et al. (2007) who did not find evidence of a statistically significant relationship between prior knowledge and proportion of acres to be converted to switchgrass.

Among the demographic variables, gender did not have a significant influence on farmer willingness to adopt switchgrass. Furthermore, the coefficient for education was statistically insignificant, contrary to our expectations. Similarly, having a primary residence on the farmland also did not have a statistically significant influence on farmer willingness to cultivate switchgrass for bioenergy.

In Table 5, we present the odds ratio and the average marginal effects for the statistically significant variables in the multivariate logistic regression. The variable for risk preference of farmers indicates that individuals who identify themselves as those who are willing to take risks if there is a possibility of earning profits have higher odds of saying "yes" to the willingness question and the results indicate an odds ratio around 7.2. The average marginal effect is the largest for the 'risk' variable. Similarly, preference for first seeing a crop being grown on extension services demonstration plots also results in higher willingness odds. Furthermore, being aware of switchgrass prior to the survey has a negative and statistically significant coefficient indicating lower odds of willingness to cultivate switchgrass. These two results highlight the role of information sharing, demonstration, and dissemination of best practices pertaining to cultivation techniques that will ensure successful establishment of switchgrass and maximized yields.

Having land under grazing as well as woodlands also positively influence farmer willingness to adopt switchgrass and thereby increase the odds of saying "yes". These results confirm our hypothesis that switchgrass, being very similar to hay, appears to be a favorable substitute crop. Furthermore, since switchgrass is also an attractive agroforestry alternative, individuals owing woodlands are also more likely to exhibit willingness to cultivate switchgrass. The average marginal effects for the land variables are very similar.

Finally, the survey also included some questions requesting the respondents to indicate the importance of certain policy alternatives. Respondents were asked to specify the relative importance they attached to policy support such in the form of price support for the produce, support for meeting capital needs during the initial 3-year period until switchgrass establishment, loan support for harvesting and marketing of produce. We evaluated the responses to these policy related questions against the backdrop farmer willingness to cultivate switchgrass. Table 6 provides the distribution of responses to these questions ($N = 100$).

Fig. 1 shows results of the contingency analysis for the questions pertaining to price support and capital support. The differences in the responses indicating the relative importance of the policy alternatives were statistically significant for the respondents who answered 'Yes' or 'No' to the willingness question. The results indicate that individuals who were willing to cultivate switchgrass were more likely to place importance on price support and capital support.

For respondents who indicated importance for price support policies the Likelihood ratio test returned a χ^2 value of 11.50 ($p = 0.021$) and for respondents who indicated importance for capital support policies the Likelihood ratio test returned a χ^2 value of 14.31 ($p = 0.006$). The US government has incentivized the cultivation of bioenergy feedstocks for several years under the Biomass Crop Assistance Program (BCAP). BCAP provided eligible farmers cost reimbursement, annual payment for annual or perennial crops, and a matching payment per tonne of biomass (USDA, 2010). However, payments under the BCAP have been cut down drastically as compared to the initial provisions of the 2008 Farm

Table 5
Odds ratio for significant variables (unweighted regression).

Variable	Odds ratio (S.E.)	Average marginal effect (S.E.)
L_hectares.grazing	1.527** (0.324)	0.059** (0.028)
L_hectares.woodland	1.526* (0.338)	0.059** (0.029)
risk	7.214*** (4.965)	0.325*** (0.111)
univ.ext	3.673* (2.645)	0.194* (0.107)
awareness	0.288* (0.197)	−0.165* (0.081)

Signif. codes:
*** 0.01.
** 0.05.
* 0.1.

Table 6
Proportional distribution of responses indicating importance of policy alternatives.

Statement	Levels	1	2	3	4	5
Price support for switchgrass similar to other agricultural products	1: Not important 2: Slightly important 3: Moderately important 4: Important 5: Very important	19.0%	6.0%	34.0%	15.0%	26.0%
Capital support program that would help finance initial costs and provide income for first 3 years until crop attains full yield	1: Not important 2: Slightly important 3: Moderately important 4: Important 5: Very important	13.0%	8.0%	27.0%	25.0%	27.0%
Commodity loans such as the Marketing Assistance Loan to meet cash flow needs during harvest	1: Not important 2: Slightly important 3: Moderately important 4: Important 5: Very important	17.0%	11.0%	36.0%	17.0%	19.0%

Bill (McMinimy, 2015). Meanwhile, farmers in our survey indicated that a capital support program, which are similar to incentives under the BCAP, is an important policy alternative to support switchgrass cultivation.

On one hand, individuals who are unwilling to cultivate switchgrass might not be induced to enter the market for switchgrass merely due to incentive programs. On the other hand, individuals who are willing to cultivate switchgrass could benefit from potential safety nets provided by such policy support. Evaluating the relative importance to the question related to loans to meet harvesting and marketing needs vis-à-vis the willingness to cultivate switchgrass yielded a result that was statistically insignificant.

6. Conclusions

Switchgrass has been identified as a high potential energy feedstock by the US Department of Energy and can be used to produce cellulosic biofuels, which can contribute towards reducing the country's consumption and dependence on non-renewable energy sources. Our study contributes to the existing literature by examining the influence of farmer risk attitudes, prior awareness of switchgrass, and importance of the role of university extension services and peers. We also evaluate variables pertaining to the land including type of land holding, experience of water stress, flooding, or erosion on the land, as well as socioeconomic characteristics. An assured year-round supply of feedstocks is one of the most important steps towards the establishment of a robust cellulosic bioenergy sector. It is likely, that the other infrastructure such as the conversion facilities, transportation and other supply chain aspects associated with cellulosic biofuel production will develop as the initial supply-side challenges are addressed. This research contributes by providing insights about farmer characteristics and preferences that can unravel some of the factors that influence farmer willingness to cultivate switchgrass.

We are able to identify several key variables, including land holding type, risk attitudes, information, and awareness that can be used to develop and design policies that will enable the farming community to adopt switchgrass cultivation and contribute towards the development of this industry. We are able to highlight the role of risk attitudes that influence farmer decisions to cultivate a bioenergy feedstock. Farmers who are willing to undertake some risks with the potential of earning profits from switchgrass cultivation are more likely to participate in this market. However, this may also indicate the need for insurance products or contracts that secure output prices for farmers who are more risk averse. We observe that policy incentives such as price support programs for switchgrass or capital support programs during the initial years until establishment could be important policy tools. We also found that information plays a key role in that farmers would like to see switchgrass being cultivated on university extension demonstration plots before they adopt it themselves.

Farmers, who were aware of switchgrass prior to the survey, were found to be less likely to be willing to cultivate switchgrass. These insights could be used to ensure that techniques for successful establishment and management are disseminated to other farmers through newsletters,

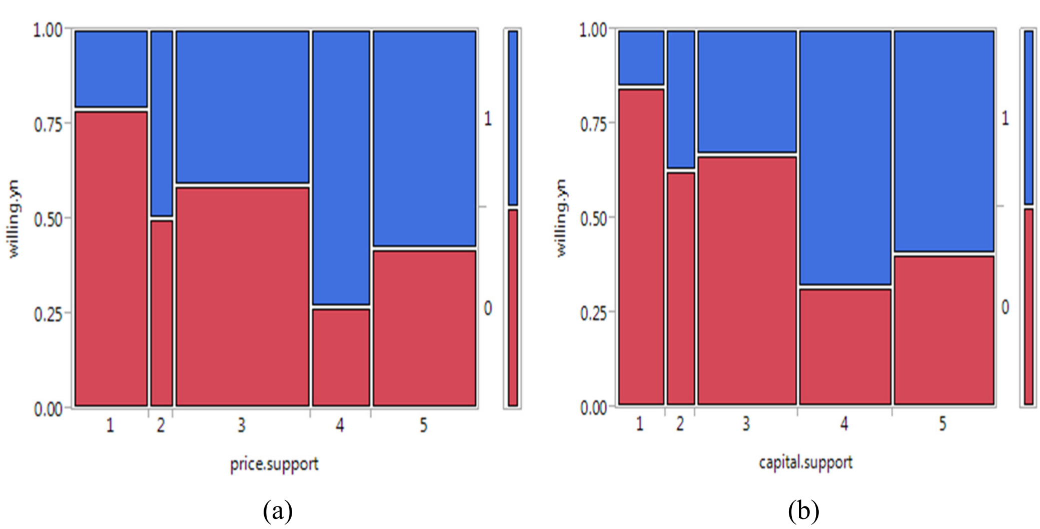

Fig. 1. Contingency tables evaluating farmer willingness to cultivate switchgrass and the importance attached to price support and capital support as policy alternatives in panels (a) and (b) respectively.

farm bureau meetings, or university extension services. Having access to the right information could allow farmers to make well-thought-out decisions and encourage them to actively seek new agricultural opportunities. However, individuals who are already willing to cultivate switchgrass would more likely benefit from them. In order to incentivize individuals to enter the market for switchgrass cultivation, policymakers might need to develop programs that not only provide financial support in a market that is in its nascent stages of development, but also engage with university extension services along with other information dissemination pathways to educate and encourage potential adopters.

Farmers with tracts of grazing land might find it relatively easier to substitute their current choices, such as hay, with switchgrass. The environmental benefits of cultivating switchgrass are several. Although variables that captured the influence of erosion, flood, drought etc. did not yield statistically significant results in the model as drivers for switchgrass adoption, disseminating these environmental benefits could be important pieces of information to the farming community. Individuals with land classified as woodlands were also found to be more willing to cultivate switchgrass, which could underscore the importance of switchgrass a suitable agroforestry alternative as well.

This study adds to the existing body of research in the area of bioenergy research and specifically farmer participation in bioenergy markets. While the results provide important insights, further research is required to determine whether these conclusions are generalizable in varied contexts and geographies. Extensive primary surveys covering a larger section of the farming community in the state of Missouri and beyond are necessary to build upon the results of this survey. One of the limitations stems from the relatively low response rate which should be addressed in future work by considering better timing for conducting the surveys and partnerships with local university extension services to encourage participation. Although more expensive, conducting in-person interviews with farmers could also help improve survey response rates. Additionally, research pertaining to other variables such as land tenure, financial constraints, prior experiences, and cultivation under contracts to safeguard farmers from downside risks could be valuable. Studies that delve into the potential land use change implications of farmer decisions to cultivate switchgrass for bioenergy can evaluate the local and regional level changes emanating from dedicated bioenergy cultivation. The net benefits from enhanced ecosystem services provided by switchgrass could also extend this research. Finally, the absence of a market for switchgrass translates into very limited information regarding the price of the feedstock. Future research can aim to address these myriad issues.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2018.12.009.

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