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SOCIO-ECONOMIC FACTORS AND ADOPTION OF ENERGY CROPS

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Abstract

Current study analyzes the socio-economic factors that impact farmers' willingness to grow switchgrass and miscanthus in Missouri and Iowa. The results of the current study show that current level of farmers' willingness to grow for either crop is low. Hence, there are barriers to accomplishing the goal of producing 21 billion gallons of cellulosic biofuel by 2022. It is also found that currently growing energy crops is more attractive to small farms as a source of crop diversification, rather than an alternative crop production system in the big scale by large farms.

Key Words: *Bioenergy, Cellulosic Ethanol, Switchgrass, Miscanthus, Technology Adoption*

1. Introduction

Concerns about the dependence on the decreasing oil reserves and the climate change have caused countries to search for alternative energy sources to decrease the dependence on fossil fuels. Bioenergy, which is produced from materials that are derived from biological sources, is one of these alternative energy sources (Sanderson et al. 2006). There have been multiple efforts in the United States to increase the use of Bioenergy. In 2007, the President of the U.S. announced the goal of cutting the gasoline consumption of the U.S. by 20 percent in 10 years (U.S. Department of Energy 2007). Ethanol has been used as biofuel additive for gasoline. Current ethanol production is based on majorly corn grain (Sanderson et al. 2006). Corn based ethanol production has been criticized due to its impact on increasing food prices and land use changes (Wilhelm et al. 2004). To overcome these problems, cellulosic ethanol production has been developed. Cellulose fiber is a major component in plant cell walls, which allows ethanol to be produced from a wide variety of plant sources that do not compete with food prices, such as switchgrass and Miscanthus, which are classified as dedicated energy crops (Wilhelm et al. 2004).

The Energy Independence and Security Act of 2007 set a renewable fuel standard of 36 billion gallons of biofuel production by 2022, of which 21 billion gallons are to come from cellulosic biofuel (U.S. Department of Energy 2007). Cellulosic biofuel production relies on energy crops to be grown by farmers. Hence, establishing a steady biomass feedstock supply is crucial for accomplishing the cellulosic biofuel production targets set by the Energy Independence and Security Act of 2007. Unlike the established corn supply for the first generation ethanol production, the cellulosic biofuel production faces uncertainties in biomass feedstock supply due to lack of established markets for energy crops.

Most of the previous research on energy crops in the field of economics focused on cost of production for these crops (Epplin 1996; Khanna et al. 2008; Hallam et al. 2001; McLaughlin & Kszos 2005). Measuring the cost of production is required, but not sufficient to promote adoption of energy crops by farmers to achieve the target levels of cellulosic ethanol production. For many farmers growing switchgrass or miscanthus for bioenergy production is new and analysis should be conducted within the context of technology adoption. Previous research on adoption of new technologies show that even profitable or cost effective technologies are not always adopted by farmers (Rahm and Huffman 1984; Koundouri et al. 2006). Other factors, such as risk and uncertainty, farm size, education, age, and off-farm income also impact the adoption decision (Feder et al. 1985; Asafu-Adjaye, 2008; Gedikoglu et al. 2011). The impact of these factors on farmers' adoption of dedicated energy crops should to be analyzed to promote development of biomass feedstock supply for cellulosic ethanol production.

The objective of this study is, through using the theory of new technology adoption, to analyze the socio-economic factors that impact farmers' willingness to grow energy crops. The current study will specifically analyze switchgrass and miscanthus. To our knowledge, this is the first study that provides a comprehensive analysis of switchgrass and miscanthus together in the context of technology adoption theory. The results of this study will guide policy makers to develop effective programs to promote adoption of energy crops. The results of this study will also show help policy makers and researchers to estimate, besides agronomical availability, the socio-economically available level of biomass feedstock from energy crops for bioenergy production.

The paper proceeds as follows: the next section provides the information on dedicated energy crops. We then provide a review of new technology adoption studies. The paper will then continue with the empirical model section, where we develop our estimation strategy. We present the results and conclude with implications for policy and extension efforts.

2. Energy Crops

In the long-term, large scale cellulosic ethanol production requires a steady supply of biomass feedstock, hence the dedicated energy crops. A steady supply of low-cost, uniform and consistent quality of biomass feedstock is required for sustainability of cellulosic ethanol industry. Department of Energy started to fund research on development of herbaceous biomass crops in 1980s (McLaughlin & Kszos 2005). A mix of several energy crops in the same region would help to reduce risk of epidemic pests and disease outbreak, and to increase supply of biomass to cellulosic ethanol plants throughout the year, as different grasses mature at different times of the year.

Switchgrass (*Panicum virgatum*) was the major crop that is analyzed as an alternative source of biomass in the United States, as it is native to North America and it has the potential of having high biomass yield per acre (McLaughlin & Kszos 2005). The other advantage of switchgrass is that it has easier adaptability to marginal land conditions (McLaughlin &Kszos 2005). Switchgrass is believed to be the most suitable for marginal lands and land with lower-opportunity costs such as pastures and land under the Conservation Reserve Program (Paine et al. 1996; Sanderson et al. 2006). Large amount of highly erodible land in Midwest is unsuitable for corn stover removal, but can be viable for switchgrass (Wilhelm et al. 2004). Switchgrass yield shows variation among studies. The study by Ugarte et al. (2003) found that the yield for switchgrass to vary between 11 ton/ha and 15 t/ha in the Corn Belt region. McLaughlin and Kszos (2005) reported that switchgrass yield ranged between 9 ton/ha and 23 ton/ha, which was depended on location and weather conditions. The study by Khanna et al. (2008) reported average switchgrass yield to be 9.42 ton / ha in Illinois and Hallam et al. (2001) reported it to be 11.3 ton/ha in Iowa. For the cost of production, the study by Hipple and Duffy (2001), conducted in southern Iowa, found the delivered costs for switchgrass to be between $75/ton and $91/ton. Cundiff and Harris (1995) found the delivered costs of switchgrass to be between $50/ton and $59/ton in Virginia. Hallam et al. (2001) reported the breakeven price for switchgrass as $47.65/ton in Iowa, whereas the same study reported the breakeven price for maize as $6.80/ton. Switchgrass is currently a high-cost crop and may not compete with commodity crops, except on marginal land with low opportunity cots (Sanderson et al. 2006).

Miscanthus (*Miscanthus* spp.) is another energy crop that has been analyzed as source of biomass. The studies show that miscanthus has higher biomass yield potential than switchgrass, which can be as high as 2.5 times (Carlson et al. 1996; Heaton et al. 2004). Studies reported the yield of miscanthus to vary between 10 ton/ha and 36 ton/ha (Bullard 1999; Lewandowski et al. 2003; Khanna et al. 2008). Miscanthus requires less fertilizer and herbicide application than switchgrass (Heaton et al. 2004). According to Heaton et al. (2004) and Khanna et al. (2008) miscanthus can be more profitable than switchgrass. Khanna et al. (2008) found the breakeven farm gate price, excluding land rent, to be $56.93/ton for switchgrass and $41.67/ton for miscanthus, based on 6 ton /ha yield for switchgrass and 19 ton /ha miscanthus. The downside of growing miscanthus is its higher establishment and operating costs than switchgrass, which can be a problem especially for small farms that has limited access to credit (Heaton et al. 2004; Khanna et al. 2008).

3. Technology Adoption

The literature on adoption of new technologies shows that even profitable or cost effective technologies are not always adopted by farmers (Rahm and Huffman 1984; Koundouri et al. 2006). Cost of production is only one of the many factors that impact farmers' adoption of a new technology. The non-adoption of profitable technologies during the "Green Revolution" led researchers to search for other factors that can impact adoption decisions of farmers. Differences in adoption decisions by small and large farms led researchers to focus on farm size as a factor that can impact adoption of new technologies (Feder et al. 1985). The impact of farm size on adoption can be through its association with factors such as economies of scale, risk aversion, and access to credit. Economies of scale in production imply average fixed costs decrease as farm size increases. Larger farms are associated with lower risk aversion and easier access to credit. Some of the empirical studies found adoption of new technology increases with farm size [Rahm and Huffman (1984) on reduced tillage; Khanna (2001) on variable rate technology; Chang and Boisvert (2005) on participating in the Conservation Reserve Program]. However, other studies found either insignificant or negative relationships [Hua et al. (2004) on conservation tillage; Koundouri et al. (2006) on irrigation technology; Soule et al. (2000) on conservation practices]. This led to other factors such as age, education and off-farm income being added into the analyses to further explain why some profitable technologies have not been adopted (a more comprehensive review of technology adoption studies can been found in Pannell et al. 2006; Gedikoglu and McCann 2010).

Age is included in analyses to represent innovativeness of the farmer and to capture the discount rate differences in future net benefits between younger and older farmers (Huffman 1980; Wozniak 1984). Younger farmers might be more innovative than older farmers. Younger farmers might also value the future net benefits more than the older farmers, as younger farmers will have more years over which they can receive the benefits from an investment. Lastly, age might be correlated with experience, hence older farmers might be more experienced than younger farmers. However, there might be cases where age is not correlated with experience. The empirical results show both positive and negative relationships between age and adoption of a new technology [Upadhyay et al. (2002) on no-tillage and continuous spring cropping; Chang and Boisvert (2005) on participating in the conservation cost share program; Soule et al. (2000) on conservation practices].

Education is assumed to provide skills to augment and use information, hence increasing farmers' ability to acquire and use information (Huffman 1980; Wozniak 1984). Most of the studies on adoption of a new technology found that the probability of adopting is increasing with human capital [Abdulai and Huffman (2005) on crossbred-cows; Barham et al. (2004) on rBST; Koundouri et al. (2006) on irrigation technology]. However, there are also studies that did not find a significant relationship between human capital and adoption [Upadhyay et al. (2002) on no-tillage and continuous spring cropping; Hua et al. (2004) on participating in a conservation program; Khanna (2001) on soil testing].

Due to its increasing share in farm households' income, studies have examined the role of off-farm income in the adoption of new technologies (Huffman 1980; Barlett 1996; Mishra et al. 2002). Mishra et al. (2002) report that either the operator, spouse, or both worked off-farm in 71% of U.S. farm households in 2002. The share of off-farm income in total farm household income rose from roughly 50% in 1969 to 90% in 2007 (U.S. Department of Agriculture 2007).

According to Gedikoglu et al. (2011), farmers with off-farm employment will have more financial resources available due to increased income, *ceteris paribus*, but will have less labor available due to time spent in off-farm activities. Hence, farmers with off-farm work are more likely to adopt capital intensive technologies, but less likely to adopt labor intensive technologies. Seasonal versus year round off-farm employment distinction is also important. Farmers with year round off-farm employment have more financial resources than farmers who do not work off the farm, but farmers with seasonal off-farm employment will also have less time available for farm activities (Gedikoglu et al. 2011). However, farmers with seasonal off-farm employment will not face the time constraint for farm activities (Gedikoglu et al. 2011). Another line of research analyzed the determinants of off-farm labor supply. Using the data from Bulgaria, the study by Goodwin and Holt (2002) found that off-farm labor supply is positively affected by education and work experience. Based on a sample in Kansas, Mishra and Goodwin (1997) found that farm income variability increases the off-farm labor supply.

4. Empirical Model

Willingness to grow (WTG) for either crop by farmers can be analyzed using an ordered probit model, as this variable takes the ordered values {1, 2, 3, 4, 5} (Greene 2008; Wooldridge 2010). Ordered probit models have been used in the literature for analyzing multinomial choice variables that are inherently ordered, for example for taste tests and opinion surveys (Greene 2008). Similar to other discrete choice models, the ordered probit model can also be derived from a random utility model (RUM) (Greene 2008; Wooldridge 2010). RUM has been used in the literature, especially in the environmental economics literature, for modeling individual's choice among discrete alternatives (Freeman, Herriges, and Kling 2014). For example, a decision maker is to choose among J alternatives. The utility that the decision maker received from choosing alternative j is represented as $U_j^*, for\ j = 1, \dots., J$.. Then the decision maker chooses the alternative that gives the maximum utility: the decision maker chooses alternative I if and only if $U_i^* > U_j^*$ for all $j \neq i$ (Freeman, Herriges, and Kling 2014; and Train 2009). The utility from each choice is known to the decision maker, but the researcher does not observe the decision maker's utility. Rather, the researcher observes some attributes of the alternatives faced by the decision maker and some attributes of the decision maker. The researcher can specify a function that relates the observed attributes to the decision maker's utility: $\mathrm{U}_\mathrm{j}^* = \mathrm{Vj} + \mathcal{E}_\mathrm{j}$ Hence, V_j represents the factors observed by the researcher and $\mathcal{E}_j$ represents the factors that affect utility but cannot be observed, hence causing U_j^* to be random.

Table 1. Comparison of Key Statistics

Variable	Data	Population*
Farm Sales		
\$10,000 - \$99,999	27%	17%
\$100,000-\$249,999	40%	36%
\$250,000 - \$499,999	21%	28%
\$500,000 +	12%	19%

Note: * Population is the combined livestock farms in Iowa and Missouri used for sampling (USDA/NASS).

For the current study the random utility from growing energy crops is assumed to be a function of age (*AGE*), education (*EDU*), off-farm employment (*OFE*), non-family labor (*HNL*), located in Missouri versus in Iowa (*LOC*), farm sales (*FSA*), leased land (*LEL*), having erosion problem (*ERO*), number of animals (*ANI*), crop production (*CRO*), being concerned about global warming (*GWM*), influence of other farmers, financial institutions, and government organizations on the farmer's decisions (*IGO*). The random component of the utility is represented with $\mathcal{E}$. The random utility function $U^*(.)$then can be represented as;

$$U^* \ (AGE, EDU, OFE, HNL, LOC, FSA, LEL, ERO, ANI, CRO, GWM, IGO;\ \mathcal{E}) \qquad (1)$$

4.1 Specific Hypotheses

The variables that impact farmers' willingness to grow switchgrass and miscanthus are chosen based on the new technology adoption literature and production characteristics for these crops, which are reviewed in the previous sections of the paper. Table 2 presents the hypothesized effect of each variable in the regression on farmers' willingness to grow for each crop. Based on the conceptual framework presented by the reviewed literature in section 3 about the impact of farm size, age, education, and off-farm income on technology adoption, we will specifically test the following hypotheses (the relevant conceptual framework / theoretical model for each variable below can be found in Gedikoglu and McCann (2010)):

Hypothesis 1: Farmers with higher farm sales are more willing to grow energy crops.
Hypothesis 2: Younger farmers are more willing to grow energy crops.
Hypothesis 3: Farmers with higher education are more willing to grow energy crops.
Hypothesis 4: Farmers with seasonal off-farm employment are more willing to grow energy crops.

4.2 Econometric Estimation

For the econometric estimation, the random utility from growing energy crops derived in equation (1) above can be represented analytically for observation i as;

$$U_i^* = X_i' \beta_i + \mathcal{E}_i \qquad (2)$$

where X_i' is the vector that includes the values for the variables that form the deterministic part of the latent variable, β_i is the vector that includes the coefficients to be estimated, $\mathcal{E}_i$ is the error term, and *i* denotes an individual observation. The error term $\mathcal{E}_i$ is assumed to have a normal distribution with mean zero and variance one. The latent variable U_i^* is unobserved, but what is observed is the willingness to grow. Let $\mu_1 < \mu_2 < \mu_3 < \mu_4$ be unknown threshold parameters, then willingness to grow is obtained as;

$$\begin{aligned} WTG_i = y_i &= 1 \; if \; U_i^* \leq \mu_1 \\ &= 2 \; if \; \mu_1 < U_i^* \leq \mu_2 \\ &= 3 \; if \; \mu_2 < U_i^* \leq \mu_3 \\ &= 4 \; if \; \mu_3 < U_i^* \leq \mu_4 \\ &= 5 \text{ if } \mu_4 < \mathrm{U}_\mathrm{i}^* \end{aligned} \tag{3}$$

Given that the error term has normal distribution, the probability of each outcome for the dependent variable can be represented as:

$$\begin{aligned} &Pr(y_i = 1|X_i) = \Phi(\mu_1 - X_i'\beta_i) \\ &Pr(y_i = 2|X_i) = \Phi(\mu_2 - X_i'\beta_i) - \Phi(\mu_1 - X_i'\beta_i) \\ &Pr(y_i = 3|X_i) = \Phi(\mu_3 - X_i'\beta_i) - \Phi(\mu_2 - X_i'\beta_i) \\ &Pr(y_i = 4|X_i) = \Phi(\mu_4 - X_i'\beta_i) - \Phi(\mu_3 - X_i'\beta_i) \\ &Pr(y_i = 5|X_i) = 1 - \Phi(\mu_4 - X_i'\beta_i) \end{aligned} \tag{4}$$

where $\Phi(.)$ is the cumulative distribution function for the standard normal distribution (Greene 2008). The log-likelihood function for the entire sample of size N can be obtained as:

$$ln\, L = \sum_{i=1}^{N} \sum_{j=1}^{5} I(y_i = j) ln Pr(y_i = j) \tag{5}$$

Maximum likelihood estimation of the coefficients β_i is obtained by taking the derivative of the log-likelihood function with respect to each coefficient included in β_i and equating to zero (Greene, 2008).

The magnitude of the partial of effect or marginal effect of a continuous variable X_k can be calculated as:

$$\frac{\partial P(y=j|X_i)}{\partial X_k} = [\phi(\mu_{j-1} - X_i'\beta_i) - \phi(\mu_j - X_i'\beta_i)]\beta_k \tag{6}$$

$\phi(.)$ is the probability density function for standard normal distribution, which is valued at the mean of the independent variables to measure the partial impact of an independent variable, X_k, on the probability of having the dependent variable take the value *j*. For a discrete variable, X_k such as a dummy variable, the magnitude of the partial effect can be calculated following Greene (2008) as:

$$\phi(B_0 + B_1 x_1 + \ldots + B_j + \ldots + B_k x_k) - \phi(B_0 + B_1 x_1 + \ldots + B_k x_k) \tag{7}$$

where X_k is equal to 1 in the first parenthesis and X_k is equal to zero in the second parenthesis.

Table 2. Variable Names, Description, Means and Hypothesized Effect on Willingness to Grow Switchgrass / Miscanthus

Variable	**Description**	**Mean** (N=369)	**Hypothesized Effect** Switchgrass / Miscanthus
Dependent Variables			
I am willing to Grow Switchgrass for Bioenergy Production	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree not disagree, 4 = agree, 5 = strongly agree	2.40	
I am willing to Grow Miscanthus for Bioenergy Production	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree not disagree, 4 = agree, 5 = strongly agree	2.00	
Independent Variables			
Age	Age of farmer in years	54	- /-
Education of Operator			
Less than high school	1 if has, 0 otherwise	0.20	- /-
High school degree	1 if has, 0 otherwise	0.29	Base
Some college or vocational school	1 if has, 0 otherwise	0.24	+/+
Bachelor degree	1 if has, 0 otherwise	0.16	+/+
Graduate degree	1 if has, 0 otherwise	0.05	+/+
Education of Spouse			
Less than high school	1 if has, 0 otherwise	0.13	- /-
High school degree	1 if has, 0 otherwise	0.15	Base
Some college or vocational school	1 if has, 0 otherwise	0.21	+/+
Bachelor degree	1 if has, 0 otherwise	0.19	+/+
Graduate degree	1 if has, 0 otherwise	0.06	+/+
Off-Farm Employment			
Operator Seasonal	1 if has seasonal off-farm work, 0 otherwise	0.10	+/+
Operator Year Round	1 if has year round off-farm work, 0 otherwise	0.33	?/?
Spouse Seasonal	1 if has seasonal off-farm work, 0 otherwise	0.05	+/+
Spouse Year Round	1 if has year round off-farm work, 0 otherwise	0.49	+/+
Hire Non-Family Labor	1 if hires non-family labor, 0 otherwise	0.33	- /-
Missouri	1 if the farm is located in Missouri, 0 if the farm is located in Iowa	0.43	?/?
Farm Sales			
\$10,000 - \$99,999	1 if has, 0 otherwise	0.27	Base
\$100,000-\$249,999	1 if has, 0 otherwise	0.40	+/+
\$250,000 - \$499,999	1 if has, 0 otherwise	0.21	+/+

Table 2. Continued

Variable	**Description**	**Mean** (N=369)	**Hypothesized Effect** Switchgrass / Miscanthus
$500,000 +	1 if has, 0 otherwise	0.12	+/+
Leased Land	1 if has leases land, 0 otherwise	0.58	- /-
Erosion Problem	1 if has erosion problem, 0 otherwise	0.66	+/+
Number of Animals	Total number of animals in animal units	212	- /-
Crop Production			
Corn	1 if grows, 0 otherwise	0.63	- /-
Soybean	1 if grows, 0 otherwise	0.49	- /-
Wheat	1 if grows, 0 otherwise	0.11	- /-
Hay	1 if grows, 0 otherwise	0.47	+/+
Pasture	1 if has, 0 otherwise	0.70	+/+
I am concerned about the global warming	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree not disagree, 4 = agree, 5 = strongly agree	2.57	+/+
Other farmers have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.55	+/+
Banks have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	1.96	- /-
Contractors have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	1.54	+/+
Extension have influence on my agricultural production decisions	Raking 1= strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree	2.16	+/+

5. Data

A mail survey of 2,995 farmers that have livestock and land for crop production or pasture in Missouri and Iowa was conducted in spring 2011. Before random sampling, farmers were stratified by farm sales. Farm sales categories were determined based on the Agricultural Census, which enabled the stratified sampling and making it possible to compare the sample with population, based on the farm sales data. A cover letter and survey were sent, followed by a postcard reminder and a second cover letter and survey. The response rate for the survey was 21%. Table 1 compares the percentage of the farmers in each farm sales category for the population sampled and the data. The highest percentage of responses was received for the farm sales category of $100,000-$249,999, which is also the category with highest number of farmers in the population. The other categories in the sample also match closely the population, except relative to the population, proportionately more survey responses were received for farm sales less than $250,000. While direct age comparisons between the data and the population are not possible given the sample stratification and the fact that only livestock producers with more than $10,000 in sales were sampled, the respondents' average age seems broadly representative of farmers in Missouri and Iowa. The average age for our sample was 54 while the average age for all farmers in Iowa and Missouri is 56 and 57 respectively according to the 2007 Census. Hence, the sample is representative of the population of the region represented by Missouri and Iowa. Our results can also be applicable to the countries with farm structures similar to Missouri and Iowa. Since the United States has states with different farm sizes, care should be given when generalizing our results for the whole United States.

Summary statistics are presented in table 2. Although willingness to grow for switchgrass is little higher than that of miscanthus, both crops have significantly low willingness to grow values. For the education, the highest category for the farm operator is the high school education, while it is some college or vocational school for the spouse. Thirty-three percent of the farm operators and forty-nine percent of the spouses had year round off-farm employment. Relatively smaller portion of farm operators and spouses had seasonal off-farm employment: Forty-three percent of the survey respondents were from Missouri and the rest were from Iowa. Forty percent of the respondents had farm sales (including both crop and livestock sales) between $100,000 and $249,999. Fifty-eight percent of the farmers had leased land. The dummy variables for crop production were generated based on if the farmer indicated a positive number of acres for the corresponding crop then the dummy variable took the value of 1, otherwise the dummy variable took the value of zero. For example, if the farmer had 10 acres of corn, then the dummy variable for corn had the value of 1 for that farmer. In the sample, sixty-three percent of the farmers grew corn and forty-nine percent grew soybean. For the influence on the agricultural production decisions, other farmers had the highest influence.

6. Results

Regression results for the ordered probit regressions are presented in Table 3. Multi-collinearity for the regression variables was checked using the variance inflation factor (VIF). The rule of thumb is to further investigate variables for which VIF is greater than 10 (Chen et al. 2006). None of the variables had VIF value that was greater than 10. Hence, there is no evidence of multi-collinearity in the regressions. Heteroskedasticity robust standard errors are used in the analysis. The p-value for the Wald Chi-square test statistic for the significance of the regression is 0.000 for both regressions, which shows that regressions are significant. The pseudo R-squared for switchgrass is 0.39 and 0.46 for miscanthus, which shows that socio-economic factors are important for adoption of energy crops.

The results of the current study show that younger farmers are more willing to grow switchgrass and miscanthus than older farmers. This is in line with the hypothesis that younger farmers are more innovative and have higher longer planning period. Education of the farm operator found to be significantly impacting willingness to grow for both crops. Farmers with bachelor degree and college degree are more willing to grow switchgrass and miscanthus than farmers with high school degree. This is in line with the hypothesis. Education was not significant for the spouse, except for switchgrass farmers whose spouses have some college or vocational school degree are less willing to grow than farmers whose spouses have high school degree. It is found that farmers whose spouse have some college or vocational school degree have less land, which can be a limiting factor for willingness to grow switchgrass, which has lower yield than miscanthus.

Table 3. Results for Ordered Probit Regressions

Variable	**Switchgrass**		**Miscanthus**	
	Coefficient	Robust S.E.	Coefficient	Robust S.E.
Age	-0.16***	0.090	-0.08**	0.011
Education of Operator (*Base = High School*)				
Less than High School	-0.81	0.439	-0.44	0.471
Some College or Vocational School	-0.25	0.321	-0.14	0.356
Bachelor	0.58***	0.363	0.58***	0.381
Graduate	0.60***	0.545	1.37***	0.601
Education of Spouse (*Base = High School*)				
Less than High School	0.07	0.454	-0.49	0.460
Some College or Vocational School	-0.01**	0.318	-0.20	0.342
Bachelor	-0.04	0.307	-0.39	0.334
Graduate	0.87	0.451	-0.36	0.510
Off-Farm Employment				
Operator Seasonal	0.15	0.324	0.78**	0.392
Operator Year Round	-0.18***	0.317	-0.25	0.329
Spouse Seasonal	0.45	0.477	0.98**	0.400
Spouse Year Round	0.58***	0.259	0.81***	0.287
Hire Non-Family Labor	0.35	0.244	0.35	0.262
Missouri (*Base = Iowa*)	0.08**	0.247	0.44*	0.290
Farm Sales (Base = $10,000-$99,000)				
$100,000-$249,999	-0.48***	0.323	-0.43**	0.348
$250,000 - $499,999	-1.18**	0.449	-0.96***	0.467
$500,000 +	-0.97	0.533	-0.33	0.585
Leased Land	1.23**	0.617	2.04**	0.856
Erosion Problem	0.37	0.259	0.17	0.268
Total Animal Units	0.00	0.013	0.00**	0.019
Crop Production				
Corn	-0.09*	0.355	-0.13**	0.354
Soybean	0.12	0.275	0.17	0.249
Wheat	-0.06	0.381	-0.08	0.433
Hay	-1.89***	0.233	-0.95*	0.260
Pasture	1.09***	0.297	0.87***	0.336
Global Warming	0.16*	0.085	0.20	0.098
Influence on Agricultural Production				
Other Farmers	-0.13	0.119	0.09**	0.124
Contractors	0.35*	0.116	0.64***	0.138

Table 3. Continued

Contractors	0.35*	0.116	0.64***	0.138
Banks	0.04	0.156	-0.26**	0.178
Extension	-0.05	0.120	-0.17	0.118
N	369		369	
Pseudo R-squared	0.39		0.46	
Wald Chi-square	123		106	
p-value for Wald chi-square	0.000		0.000	

Seasonal off-farm employment has the expected sign for both crops, but significant only for miscanthus. Hence, the hypothesis is only supported for switchgrass. Since establishing miscanthus is more costly, the impact can be more significant for this crop. Year round off-farm employment has negative coefficient for both crops, but only significant for switchgrass. Since switchgrass requires more management than miscanthus, the time constraint of farmers is seen more influential for switchgrass. Year round off-farm employment of the spouse is significant for both crops, although year round off-farm employment is significant only for miscanthus. Hence, there is evidence that the spouse's off-farm employment provides an additional financial source that enhances the farmer's willingness to grow energy crops that are costly to grow.

Farm sales categories are significant for both crops. Farmers with farm sales categories of \$100,000-\$249,999 and \$250,000-\$499,000 are less willing to grow switchgrass and miscanthus than the farmers in the base category. This result contradicts to the hypothesis. Small farms might see energy crops as a source of alternative income and diversifying the source of farm income to minimize the farm income risk (Wondimagegn et al. 2011). On the other hand, larger farms might not feel the need to diversify crop production and continue to specialize on certain crops and livestock species and benefit from economies of scale (Wondimagegn et al. 2011).

Farmers in Missouri are more willing to grow switchgrass and miscanthus than farmers in Iowa, which may relate to the more cropping-intensive nature of farming systems in that Iowa (Hoag and Roka 1995). Farmers with leased land are found to be more willing to grow switchgrass and miscanthus. It is expected that farmers who lease land are less willing to grow energy crops due to longer establishment periods for these crops. This point requires further research.

Farmers with corn production are found to be less willing to grow either crop, which is expected due to opportunity cost of converting land from corn to energy crops. Also in line with the expectation, farmers with hay production are less willing to grow switchgrass and miscanthus. Also, farmers that have pasture are found to more willing to grow both crops. Being concerned about global warming has the expected sign for both crops, but statistically significant for only switchgrass.

Influence of different sources on agricultural production decision of the farmer is significant especially for miscanthus. Farmers who are influenced by the contractors are more willing to grow both switchgrass and miscanthus. Other farmers have positive and significant impact for miscanthus, but not for switchgrass. On the other hand, banking institutions have negative impact for miscanthus. It could be that farmers believe that banks would not give credit for growing miscanthus, due its high establishment cost and not having established markets for energy crops. Surprisingly, extension has negative coefficient for both crops, but variable not statistically significant.

Table 4. Marginal Effects for Willingness to Grow (WTG) for Ordered Probit Regressions

Variable	**Switchgrass**						**Miscanthus**				
	WTG = 1	WTG = 2	WTG = 3	WTG = 4	WTG = 5		WTG = 1	WTG = 2	WTG = 3	WTG = 4	WTG = 5
Age	0.01	0.00	-0.02	-0.01	0.00		0.00	0.00	-0.02	-0.02	- 0.01
Education of Operator (Base = High School)											
Less than High School	-0.14	-0.14	0.23	0.05	0.00		-0.16	-0.20	0.36	0.00	0.00
Some College or Vocational School	-0.09	-0.06	0.13	0.01	0.00		0.01	0.01	-0.02	0.00	0.00
Bachelor	-0.32	-0.27	0.23	0.32	0.04		-0.38	-0.32	0.64	0.06	0.00
Graduate	-0.20	-0.25	-0.52	0.25	0.72		-0.20	-0.30	-0.40	0.89	0.02
Education of Spouse (Base = High School)											
Less than High School	0.19	0.06	-0.24	-0.01	0.00		0.55	0.01	-0.56	0.00	0.00
Some College or Vocational School	0.25	0.09	-0.32	-0.02	0.00		0.21	0.10	-0.31	0.00	0.00
Bachelor	0.20	0.08	-0.27	-0.02	0.00		0.20	0.10	-0.30	0.00	0.00
Graduate	0.26	0.06	-0.32	-0.01	0.00		0.02	0.01	-0.03	0.00	0.00
Off-Farm Employment											
Operator Seasonal	0.04	0.02	-0.06	0.00	0.00		-0.18	-0.26	0.44	0.01	0.00
Operator Year Round	0.46	0.15	-0.55	-0.05	0.00		0.06	0.04	-0.10	0.00	0.00
Spouse Seasonal	-0.02	-0.01	0.02	0.00	0.00		-0.16	-0.27	0.42	0.02	0.01
Spouse Year Round	-0.45	-0.16	0.55	0.06	0.00		-0.47	-0.19	0.66	0.00	0.00
Hire Non-Family Labor	-0.06	-0.03	0.08	0.01	0.00		-0.10	-0.09	0.19	0.00	0.00
Missouri (Base = Iowa)	-0.19	-0.15	0.28	0.05	0.00		-0.15	-0.14	0.29	0.00	0.00

Table 4. Continued

Variable	**Switchgrass**						**Miscanthus**				
	WTG = 1	WTG = 2	WTG = 3	WTG = 4	WTG = 5		WTG = 1	WTG = 2	WTG = 3	WTG = 4	WTG = 5
Farm Sales (Base = $10,000-$99,000)											
$100,000-$249,999	0.43	0.10	-0.50	-0.03	0.00		0.35	0.12	-0.47	0.00	0.00
$250,000 - $499,999	0.48	0.06	-0.52	-0.02	0.00		0.82	-0.07	-0.75	0.00	0.00
$500,000 +	0.06	0.03	-0.08	-0.01	0.00		-0.06	-0.05	0.11	0.00	0.00
Leased Land	-0.39	-0.09	0.46	0.02	0.00		-0.62	-0.06	0.67	0.00	0.00
Erosion Problem	0.09	0.05	-0.13	-0.01	0.00		-0.10	-0.08	0.18	0.00	0.00
Total Animal Units	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
Crop Production											
Corn	0.18	0.20	-0.25	-0.12	-0.01		0.20	0.29	-0.47	-0.01	0.00
Soybean	0.12	0.11	-0.20	-0.04	0.00		0.05	0.05	-0.10	0.00	0.00
Wheat	-0.07	-0.06	0.11	0.01	0.00		0.09	0.05	-0.15	0.00	0.00
Hay	0.24	0.24	-0.26	-0.21	-0.02		0.15	0.17	-0.32	0.00	0.00
Pasture	-0.36	-0.12	0.44	0.03	0.00		-0.48	-0.14	0.61	0.00	0.00
Global Warming	-0.08	-0.05	0.11	0.01	0.00		-0.05	-0.04	0.09	0.00	0.00
Influence on Agricultural Production											
Other Farmers	0.09	0.05	-0.13	-0.01	0.00		-0.12	-0.09	0.21	0.00	0.00
Contractors	-0.11	-0.07	0.16	0.01	0.00		-0.17	-0.13	0.31	0.00	0.00
Banks	0.05	0.03	-0.07	-0.01	0.00		0.11	0.09	-0.20	0.00	0.00
Extension	0.00	0.00	0.00	0.01	0.00		0.07	0.06	-0.13	0.00	0.00

Lastly, we conducted a sensitivity analysis using alternative estimation of Ordinary Least Squares (OLS). The statistical significance and sign of the coefficients did not change when the OLS regression is used instead of ordered probit regression for both switchgrass and miscanthus. Hence, our regression results are robust. Following Greene (2008), ordered probit regression is preferred to the OLS regression, as OLS regression does not take in account the discrete structure of the dependent variables in the current study.

6.1. Marginal Effects

Marginal effects were also calculated to determine which factors had a large impact on farmers' willingness to grow switchgrass and miscanthus, in addition to being statistically significant. Table 4 presents the marginal effects for both crops for all willingness to grow levels. Since willingness to grow levels take the ordered values {1, 2, 3, 4, 5}, five marginal effects are calculated for each variable for each crop separately. The sign of a variable is expected to change across different levels of willingness to grow. For example having a bachelor degree of farm operator is found to influence willingness to grow switchgrass positively. Hence, this variable is expected to have negative marginal effects for lover levels one and two and positive affect on higher levels four and five.

Overall, majority of the variables that are significant in the regression are also found to be highly influential in the marginal effects, such as education of the farm operator, off-farm employment and the farm sales categories. This helps to identify the factors to focus on to promote production of these crops by the farmers. While found statistically significant in the regression, being concerned about the global warming does not have high marginal effects. Hence, farmers' skills and financial and time constraints are the most influential factors that will impact adoption of energy crops.

7. Conclusion

Accomplishing the targets of cellulosic bioenergy of the Energy Independence and Security Act of 2007 require that farmers grow energy crops such as switchgrass and miscanthus. Current study analyzed the socio-economic factors that impact farmers' willingness to grow switchgrass and miscanthus in Missouri and Iowa. The results of the current study show that currently the willingness to grow for energy crops is low. This study provided evidence that policy makers and researchers should consider the socio-economic barriers when estimating the amount of biomass feedstock that will be provided by the farmers for bioenergy production. The realized amounts biomass feedstock supply can be significantly lower than the estimated amount, socio-economic barriers are not considered.

The results of the current study showed that farmers' education, off-farm employment, and farm sales are important factors that impact farmers' willingness to grow energy crops. The results showed that smaller farms are more willing to grow energy crops. Due to yield and price uncertainty, and already high commodity prices, larger farms might not willing to grow energy crops. Small farms and especially the ones that have pasture will be the likely growers of energy crops. This study showed that farmers' willingness to grow is not impacted from their interaction with extension services. Hence, new extension and education programs should be developed to promote adoption of energy crops. Finally, there might be differences in adoption of different energy crops. Hence, different policies might be needed to promote adoption of different energy crops.

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