Contracting in the Presence of Insurance: The Case of Bioenergy Crop Production

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Selected paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 Annual Meeting, Minneapolis, Minnesota, July 27-29, 2014.

1. Introduction

The commercialization of cellulosic biofuel production requires a steady and sufficient supply of feedstock which is expected to be provided by dedicated energy crops, such as miscanthus and switchgrass. Similar to conventional crops, yield and price risks will be prevalent in bioenergy crop production. Moreover, the availability of crop insurance for conventional crops makes the production of energy crops without crop insurance even riskier than otherwise. Crop insurance program is also enhanced in the 2014 Farm Bill, in that the crop insurance coverage is expanded and the crop insurance outlays are projected to be $90 billion over the next 10 years (Chite 2014). Therefore, risk management strategies and the need for coordination of biomass supply between farmers and biorefineries are likely to necessitate reliance on long term contracts and on insurance programs for bioenergy crops.

The purpose of this paper is to investigate how crop insurance for energy crops will affect the optimal contract design and land allocation under a certain contract type. A few recent studies have investigated contracting for energy crops or the effects of crop insurance on bioenergy crop production (Miao and Khanna 2014; Yang, Paulson, and Khanna 2012). However, none of these studies considers the interaction between contracting and crop insurance for energy crops. This interaction is of interest because as two major risk management tools in agricultural production, contracting and crop insurance may substitute or complement each other. How will the presence of crop insurance for bioenergy crops affect farmers' contracting choices and contract terms? How will farmers' welfare and biorefineries' profits be influenced by the crop insurance? Could the social benefits of crop insurance for energy crops justify its costs were the insurance programs to be supported by the government? This study addresses these questions. The framework developed here is applicable not only for bioenergy crop production, but for livestock

production under which contracting is the dominant industrial organization format while there is an increasing demand for government supported insurance.

We investigate the interaction of crop insurance and contracts in improving the risk management ability of farmers who produce energy crops. We also investigate a spectrum of policy alternatives and evaluate their effectiveness in promoting the adoption of energy crops. The paper is organized as follows. In the next section, we review the previous literatures about the relationship between insurance and contracts. In section 3, we describe the setup of the model. Data and simulation results are discussed in section 4 and section 5. Section 6 concludes.

2. Literature Review

There are both empirical and analytical studies which identify the relationship between insurance and contract. Some studies investigate the impact of crop insurance on the adoption of marketing practices including contracting. Sartwelle et al. (2000) surveyed farmers in Kansa, Texas and Iowa to identify the determinants of their grain marketing practices. The marketing tools in this study include: cash market, forward contract and futures and options oriented marketing practices. One variable they use to measure insurance is whether Multiple Peril Crop Insurance (MPCI) or Crop Revenue Coverage (CRC) crop insurance is used regularly or not. In their analysis, 77% of respondents use some form of crop and/or revenue insurance. Their results show that use of either multi-peril crop insurance and/or crop revenue coverage decreases the amount of cash market transactions, and increases the amount of forward contract and futures and options marketing. The implication of this result is that farmers who purchase crop insurance make greater use of forward contracts, futures and options marketing tools than those who do not purchase crop insurance because crop insurance and forward pricing tools can be used jointly to manage income risk.

Paulson, Katchova, and Lence (2010) examine farmers' decision to produce corn or soybean under marketing contract agreements using USDA's Agricultural Resource Management Survey (ARMS) data. They tried a set of risk-related explanatory variables and find that crop insurance has a significant effect on contracting. Farmers who purchase some form of crop insurance are more likely to use corn and soybean marketing contracts. The presence of crop insurance increased the probability of adopting corn and soybean contract by 13.17% and 8.32% respectively. Their explanation of this result is that yield insurance covers the yield risk that could exacerbate losses under a marketing contract, reducing the risk of farmer not being able to deliver on a contract. Revenue insurance covers both yield and price risk, reducing the incentive to enter into a marketing contract to manage price risk.

Goodwin and Schroeder (1994) also report the role of crop insurance in farmers' adoption of forward and futures marketing methods. They collect data of 509 Kansas wheat, corn, sorghum, soybean, cattle and hog producers, and evaluate farmers' adoption decisions using probit model and adoption levels using tobit model. The authors find that farmers' adoption probability was 10.6% higher for producers who purchased federal crop insurance. Crop insurance purchases are positively correlated with adoption levels in all crops, but it is not significant predictor.

Contrary to the previous studies, Shapiro and Brorsen (1988) find that crop insurance is not a significant predictor of farmers' hedging behavior. A significant factor related to hedging is whether hedging is perceived to increase income stability. Farmers are more likely to hedge when they are highly leveraged. This study may not have a wide implication for the general population because of the small sample size (42 farmers) and non-randomness (all workshop participants in the 1985 Top Farmer Crop Workshop at Purdue University).

Another strand of studies examines the simultaneous adoption of contracting and insurance. A farmer optimizes his insurance and contracting decisions jointly instead of independently. Coble, Heifner, and Zuniga (2000) set up an analytical model to investigate the optimal futures and options in the presence of four alternative insurance coverage. They also use farm-level yield information to numerically investigate the interaction of yield and revenue insurance with forward pricing instruments. They find that the yield insurance has a positive effect on the optimal quantity hedged and revenue insurance tends to result in slightly lower hedging demand than the one under yield insurance. Yield insurance is complementary to hedging while revenue insurance design has a strong substitution effect on hedging.

Built on the work of Coble, Heifner, and Zuniga (2000), Coble et al. (2004) examine the interaction between alternative insurance designs, forward pricing tools and a government price support. They design an analytical model to illustrate the substitution of loan programs for hedging. They also introduced futures prices, basis and yield variability in the numerical analysis. They find a strong substitution effect between the price support programs and the market-based tools and insurance. They also find revenue insurance substitute for futures contracts, which is consistent with the findings of Mahul and Wright (2003).

In addition, Velandia et al. (2009) analyze the factors that determine the adoption of crop insurance, forward contracting and spreading sales using multivariate and multinomial probit models. They also consider the case of simultaneous adoption and correlation among three risk management adoption decisions. They set up an expected utility framework to model farmers' decision on risk management tools. It assumes that the risk management tools affect the distribution of net return for every farmer. Farmers will select management tools which yields a higher certainty equivalent net return compared with no risk management tools. They collect the

data from corn and soybean farmers in Illinois, Indiana and Iowa and find that the decision to adopt crop insurance, forward contracting and/or spreading sales are correlated. In addition, the adoption of one risk management tool positively influences the decision to adopt other tools.

3. Model Setup

We develop a conceptual framework where farmers maximize their profit through optimal land allocation and contract choice. A farmer with a total land of one unit may choose to grow energy crops under any of the contracts or continue to grow conventional row crops on land parcel i. Suppose he would devote $l_C \geq 0$ acres of land into conventional crops and $l_E \geq 0$ acres of land into energy crops. Let $\pi_{it}^{\ C}$ and $\pi_{it}^{\ E}$ be the per-acre profit from growing conventional crops and energy crops respectively. There are three types of energy crop contracts available ($E1, E2$, and $E3$), each contract arrangement yields a profit for farmer i ($\pi_{it}^{\ E1}$, $\pi_{it}^{\ E2}$, and $\pi_{it}^{\ E3}$). $\pi_{it}^{\ E}$ is the maximum profit a farmer could get from the optimal contract arrangement. The utility function is a constant absolute risk aversion (CARA) utility function with functional form $U(\pi_{it}) = 1 - e^{-\alpha\pi_{it}}$.

A landowner of parcel *i*, with utility discount rate $r \in [0,1]$, allocate her land and choose contracts to maximize her net present value of expected utility over the lifespan of energy crops T years as follows:

$$Max_{\{l_C, l_E\}} \sum_{t=1}^{T} \left(\frac{1}{1+r}\right)^{t-1} E(U(l_C \pi_{it}^{\ C} + l_E \pi_{it}^{\ E})) \quad \text{where}$$

$$s.t. \quad l_C + l_E = 1$$

$$\pi_{it}^{\ E} = \max\{\pi_{it}^{\ E1}, \pi_{it}^{\ E2}, \pi_{it}^{\ E3}\}$$

For conventional crops, a farmer's per-acre profit is,

$$\pi_{it}^{\ C} = P_t^C Y_t^C - V_t^C Y_t^C - F_t^C + I_t^C - (1 - s^C) E(I_t^C) \quad \text{for } t = 1, \ldots, T \tag{1}$$

The price and yield of conventional crops are denoted by P_t^C and Y_t^C. The fixed production cost and variable production cost are represented by F_t^C and V_t^C. We assume conventional crops are covered by revenue insurance. The indemnity of the conventional crop is $I_t^C = \max[\phi^C E(P_t^C Y_t^C) - P_t^C Y_t^C, 0]$. The premium of the conventional crop insurance is $E(I_t^C)$. Part of the insurance premium (s^C) is paid by the government, a farmer needs to pay the remaining part of it ($1 - s^C$).

We consider three types of energy crop contracts: land leasing contract, fixed price contract and revenue sharing contract. Under land leasing contract ($E1$), landowners are offered a fixed rental rate ω per acre per year for the contract period $t \in \{1,...,T\}$ to lease their land to the refinery to produce bioenergy crops. Therefore, farmer' per-acre profit is,

$$\pi_{it}^{E1} = \omega \quad \text{for } t = 1,...,T. \tag{2}$$

Under fixed price contract ($E2$), the farmer produces energy crop on his land and agrees to deliver their total production of biomass Y_{bt} to the biorefinery from year three onwards at a fixed price $\overline{P_y}$ per ton of biomass. The per-acre profit under fixed price contract is:

$$\pi_{it}^{E2} = \begin{cases} -(1-\rho)F_{bt} & \text{if } t = 1,2 \\ (P^S + \overline{P_y})Y_{bt} - V_b + I_t^E - (1-s^E)E(I_t^E) & \text{if } t = 3,...,T \end{cases} \tag{3}$$

We assume the first year of the energy crop lifespan is the establishment stage. F_{bt} is the establishment cost of energy crops in year one and year two, V_b is the variable operating cost in year three and onwards. Establishment cost share borne by the government is represented by parameter ρ, the remaining part ($1-\rho$) is paid by the farmer. We assume that there is a yield insurance program available for energy crops. The indemnity of the energy crops in year t is

represented by $I_t^E = \overline{P}\max[\phi^E E(Y_{bt}) - Y_{bt}, 0]$. ϕ^E is the crop insurance coverage level for energy crops. $\overline{P}$ is the average biomass futures price over five years. $E(\bullet)$ is the expectation operator. The farmer receives an insurance subsidy at a rate of s^E. Farmers also receive biomass price subsidy from the government. Biomass price subsidy is denoted by parameter P^S.

Under revenue sharing contract ($E3$), the biorefinery pays a price indexed to its revenue for the total production of biomass Y_{bt}. The price is a pre-specified α percent of its revenue $P_{et}G$ generated per ton of biomass supplied by the landowner and converted to G gallons of ethanol that is sold at the market price P_{et} per gallon.

The farmer's per-acre profit from the revenue sharing contract is:

$$\pi_{it}^{E3} = \begin{cases} -(1-\rho)F_{bt} & \text{if } t = 1,2 \\ (P^S + \alpha P_{et}G)Y_{bt} - V_b + I_t^E - (1-s^E)E(I_t^E) & \text{if } t = 3,...,T \end{cases} \tag{4}$$

Compared with the fixed price contract, the indemnity of the energy crops in year t in revenue sharing contract is represented by $I_t^E = \overline{P}\max[\phi^E E(Y_{bt}) - Y_{bt}, 0]$.

The credit constraint is also considered an important factor which determines the adoption of energy crops. Equation (3) and (4) shows the case when there is a credit constraint because farmers finance themselves. When there is no constraint, farmers could finance their establishment stage investment using credit market. We further assume that the net present value of the loan equals to the net present value of the annuities and the farmers obtain the loan to pay for their part of the establishment cost.

We assume there is one representative biorefinery in this region. The capacity of the representative biorefinery is fixed at one billion gallons per year. The biorefinery's problem is to find the optimal contract terms which could attract farmers to enroll into the energy crops to

guarantee that the biomass supply target is met. The essence of biorefinery's problem is a biomass cost minimization problem subject to capacity constraint. In this setup, we assume the biorefinery is responsible for all the transportation cost from the field to the biorefinery. We do not specify the geographical location of the biorefinery. We concentrate our analysis on the contract arrangement and farmers' land allocation decisions instead of biorefinery's location selection problem. Our simplified assumptions on biorefinery location and transportation cost won't affect the optimal contract terms and farmers' land allocation decisions.

4. Data and Simulation

We use historical data on crop yields and prices of conventional crops and simulated data for yields of energy crops. Yields of corn and soybeans over 1979-2010 and across the rain-fed area of U.S. are obtained from National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture (USDA). There are a total of 1,795 counties included in our analysis.

In the absence of observed data from commercial production of miscanthus in the United States, several studies have used crop growth models to simulate miscanthus yield based on data obtained from experimental fields. Kiniry *et al*. (1992) developed a general crop growth model, namely ALMANAC, which has been used in several site-specific studies to simulate the yield of switchgrass (Kiniry *et al*. 1996, 2005; McLaughlin et al. 2006). Originally developed for Ireland to predict miscanthus yield, MISCANMOD has been used to simulate the yield of miscanthus across Europe (Clifton-Brown, Stampfl, and Jones 2004). Most recently, Miguez *et al*. (2012) developed a sophisticated semi-mechanistic dynamic crop growth and production model to simulate the yield of miscanthus in the United States.

We model energy crop yields using the DayCent model, the daily time-step version of the CENTURY biogeochemical model that can simulate plant growth based on information of

precipitation, temperature, soil nutrient availability, and land-use practice (Del Grosso *et al.* 2011). Observed yield data from field experiments growing miscanthus and several switchgrass cultivars were used to calibrate the productivity parameters that related soil attribitutes and weather with yields in DayCent (Hudiburg *et al.* forthcoming; Dwivedi *et al.*, 2014). The model was then used to simulate yield of miscanthus and switchgrass on both cropland and pastureland (referred to hereafter as marginal land) in the rainfed area of the United States for a 30-year period based on county-specific historical weather information for the 1980-2003 period assuming 24-year cycling of weather patterns. In this study we focus on miscanthus. Corn and soybean yield data over the same period are obtained from National Agricultural Statistics Service (NASS) of U.S. Department of Agriculture (USDA). Other technical and economic data such as biofuel production cost, conversion efficiency of biomass to biofuel, biomass transportation cost are obtained from related literature.

Our simulation approach is to find the optimal contract term which could attract potential farmers to enroll into energy crops to guarantee the annual capacity of the biorefinery. For each level of contract term, we calculate farmers' profit of row crops and energy crops respectively based on their yield and price distribution. Farmers allocate their land between row crops and energy crops to maximum their expected utility over the life cycle of the energy crops. We simulate the model under different credit constraint scenarios. We also tried different levels of risk preference and time preference coefficients to test the sensitivity of our results.

5. Results

Our analysis can be divided into the following cases. We use fixed price contract as an example to illustrate the effect of alternative parameter specifications. We assume there is energy crops insurance for farmers who choose to grow energy crops in the baseline case. First, we analyze

the effect of time preference on contract terms and land allocation and report the results in Table 1. We also examine the effect of farmers' risk preference on contract terms and land allocation and summarize our results in Table 2. We then examine the effect of energy crop insurance on optimal contract terms and land allocation decisions. The results are presented in Table 3.

5.1 Effect of Credit Constraint

We specify two scenarios regarding credit constraint. One is no credit constraint scenario under which farmers could borrow from credit market freely and smooth their consumption over years. The other is credit constraint scenario under which farmers could not borrow from credit market in the establishment stage.

From Table 1 we observe that farmers with credit constraint require a much higher contract price to grow energy crops compared with farmers without credit constraint. For a farmer without credit constraint and has a low discount rate, the biorefinery need to pay him $57.31/ton to enroll him into the fixed price contract. While for a farmer who is credit constrained and has a low discount rate, the biorefinery needs to pay $61.18/ton to enroll him into the contract. For a medium discount rate farmer, the biorefinery needs to pay an additional $4.76/ton if the farmer is credit constrained. For a high discount rate farmer, the biorefinery needs to pay additional $6.43/ton if a farmer is credit constrained.

We find the same pattern in Table 2. Credit constraint has a negative impact on the contracted price terms. Farmers without credit constraint could borrow money from the credit market and spread the cost over the life cycle of the energy crops, thus they request lower contracted price. While for farmers who could not borrow from credit market, their consumption level in the establishment stage will be low, which makes the energy crops choice less attractive.

The biorefinery needs to pay a much higher price to compensate farmers for the initial low consumption level.

5.2 Effect of Discount Rates

We run our model with three levels of utility discount rate. In the baseline case, the discount rate is set at 0.05. We also examine the low discount rate scenario (discount rate equal to 0.02) and high discount rate scenario (discount rate equal to 0.1). We find that discount rate has a positive effect on the contracted biomass price for farmers without credit constraint as well as farmers with credit constraint. Under a low utility discount rate, if there is no credit constraint then the optimal fixed price contract is $57.31/ton. If there is a credit constraint, however, then the optimal fixed price in the contract is $61.18/ton. The contracted price for farmers with high discount rate increases to $66.89/ton and $73.32/ton for no credit constraint and with credit constraint case, respectively. Farmers with low discount rate are more patient, they care about the cash flow in the life cycle of energy crops. Farmers with higher discount rate care more about the current cash flow instead of the return in the future. In order to attract farmers with high discount rate, the biorefinery needs to pay a higher price premium.

The discount rate also has an impact on the land allocated to energy crops. Generally speaking, more land is allocated to energy crops when farmers have a low level of discount rate. More land is devoted to traditional row crops when farmers have a high level of discount rate. This result is driven by the initial investment in the establishment stage and later returns for energy crops.

5.3 Effect of Risk Preferences

The effect of risk preference also depends on the credit constraint conditions. Without credit constraints, farmers with high risk aversion coefficient request a lower contracted price term. In

this case, the yields of row crops are more risky compared with energy crops for farmers without credit constraint. With credit constraint, farmers who are more risk averse tend to request a higher level of biomass price. This result reflects that the credit constraint is a key factor which determines the comparative advantage of row crops and energy crops.

The risk preference also affects the land allocation patterns. Farmers with high levels of risk aversion coefficient are more likely to devote their land into energy crops production, while farmers with low levels of risk aversion coefficient are more likely to allocate their land into row crops production.

5.4 Effect of Energy Crop Insurance

Insurance also plays a role in determining the optimal contract terms. We report the results about the insurance policy in Table 3. From Table 3, we can observe that the biorefinery needs to pay more if there is no insurance policy available. The biorefinery need to pay $66.11/ton to farmers with credit constraint if there is no insurance policy, while the biorefinery pays $65.36/ton if there is an energy crop insurance policy. For farmers without credit constraint, the biorefinery needs to pay them $61.35/ton if there is no insurance versus 60.60/ton with insurance. Energy crop insurance is a risk management tool for farmers. It can also alleviate the biomass acquisition cost for the biorefinery.

From Table 3, we can also observe that the impact of crop insurance is not as big as the impact of credit constraint. This is because the contract is a risk management tool, which shares some of the risk management features of the energy crop insurance. We expect substitute effect between energy crop insurance and contract arrangement. Farmers need to bear the credit constraint over the life cycle of the energy crops unless they have an alternative source to smooth their consumption.

5.5 Land Allocation Distribution

The geographical distribution of land allocated to energy crops across 1,795 counties is illustrated in Figure 1 and Figure 2. Figure 1 shows the land allocation if energy crop insurance is available. Figure 1.1 is the land allocated to energy crops when there is no credit constraint. The average energy crop production is the highest in the state of Missouri, Illinois, Texas, and Mississippi. Figure 1.2 shows the change of land distribution when credit constraint is imposed. Large amount of land opt out of the energy crops production in Arkansas, Illinois, Kansas, and Louisiana. More land is converted into energy crop production in Indiana, and Maryland. Figure 2 shows the land allocation when energy crop insurance is not an option for farmers. Figure 2.1 is the land allocated to energy crops when there is no credit constraint. The energy crop production area is concentrated in the state of Illinois, Missouri, Texas, and Mississippi. Figure 2.2 shows the change of land distribution when credit constraint is imposed. Large amount of land opt out of the energy crops production in Illinois, Kansas, Arkansas, and Mississippi. More land is converted into energy crop production in Indiana, New Jersey, Kentucky, and Missouri.

6. Conclusions

In this paper, we investigate the interaction of crop insurance and contracts in improving the risk management ability of farmers who produce energy crops. We set up a farmer profit maximization framework to analyze the optimal contract choices of potential farmers. In addition we utilize national row crop yield data and energy crop yield data to simulate the model. We also investigate the effect of farmers' time preference and risk preference on the optimal energy crop contract terms. We find that farmers with credit constraint requested a higher contract term. Farmers with high discount rate request a higher contract terms and the impact of risk preference also depends on the credit constraint conditions. Energy crops insurance also affects the optimal

contract term of energy crops. If energy crop insurance is provided, the biorefinery will incur a lower cost to acquire the same amount of biomass.

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Table 1. The Impact of Time Preference on Fixed Price Contract Terms and Land Allocation

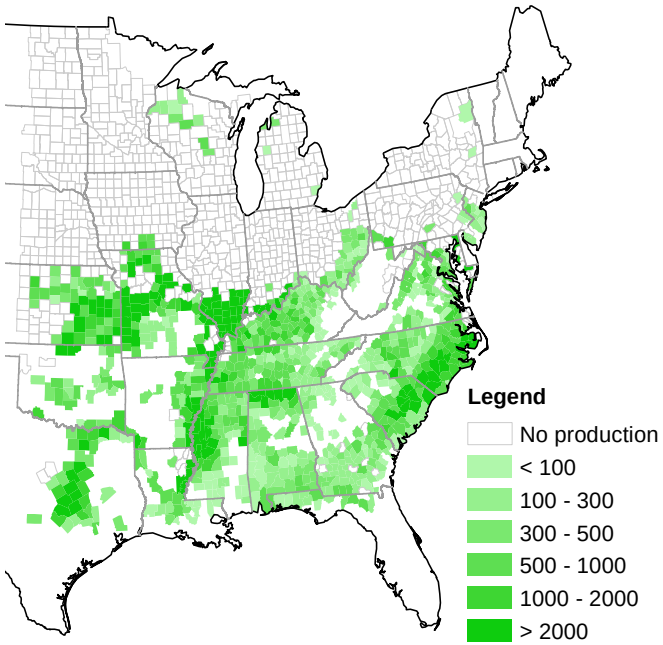
Scenarios	Discount Rate	Fixed Price Contract Term ($/ton)	Average Land Allocated to Energy Crops per county (acres)	Average Land Allocated to Row Crops per county (acres)
Without Credit Constraint				
Low Discount Rate	0.02	57.31	739.55	68,930.23
Medium Discount Rate	0.05	60.60	736.89	68,931.64
High Discount Rate	0.1	66.89	733.85	68,933.78
With Credit Constraint				
Low Discount Rate	0.02	61.18	746.26	68,925.36
Medium Discount Rate	0.05	65.36	744.97	68,925.04
High Discount Rate	0.1	73.32	743.15	68,924.95

Table 2. The Impact of Risk Preference on Fixed Price Contract Terms and Land Allocation

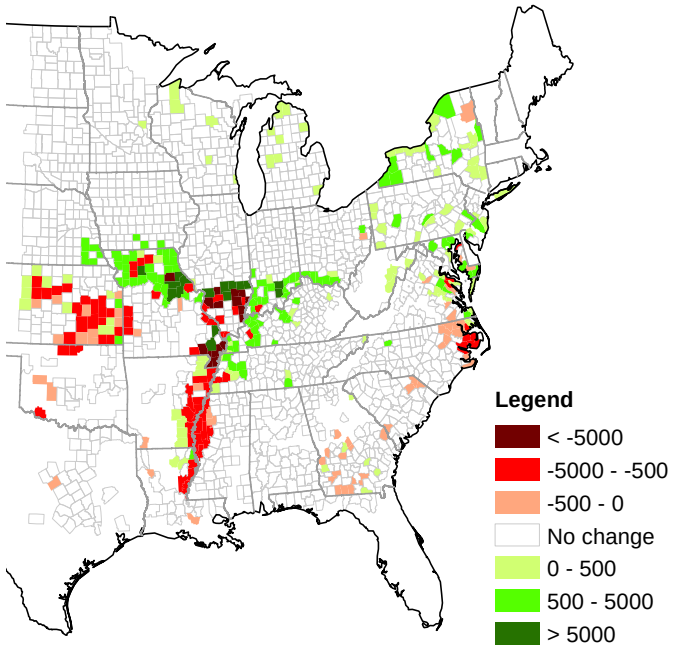
Scenarios	Risk Preference	Fixed Price Contract Term ($/ton)	Average Land Allocated to Energy Crops per county (acres)	Average Land Allocated to Row Crops per county (acres)
Without Credit Constraint				
Low Risk Preference	0.000005	61.47	736.67	68,939.20
Medium Risk Preference	0.00001	60.60	736.89	68,931.64
High Risk Preference	0.00005	56.96	773.06	68,847.67
With Credit Constraint				
Low Risk Preference	0.000005	63.89	741.12	68,936.34
Medium Risk Preference	0.00001	65.36	744.97	68,925.04
High Risk Preference	0.00005	72.67	809.01	68,808.16

Table 3. The Impact of Energy Crop Insurance on Fixed Price Contract Terms and Land Allocation

Scenarios	Fixed Price Contract Term ($/ton)	Average Land Allocated to Energy Crops per County (acres)	Average Land Allocated to Row Crops per County (acres)
Without Energy Crop Insurance			
Without Credit Constraint	61.35	736.86	68,931.21
With Credit Constraint	66.11	744.33	68,925.07
With Energy Crop Insurance			
Without Credit Constraint	60.60	736.89	68,931.64
With Credit Constraint	65.36	744.97	68,925.04

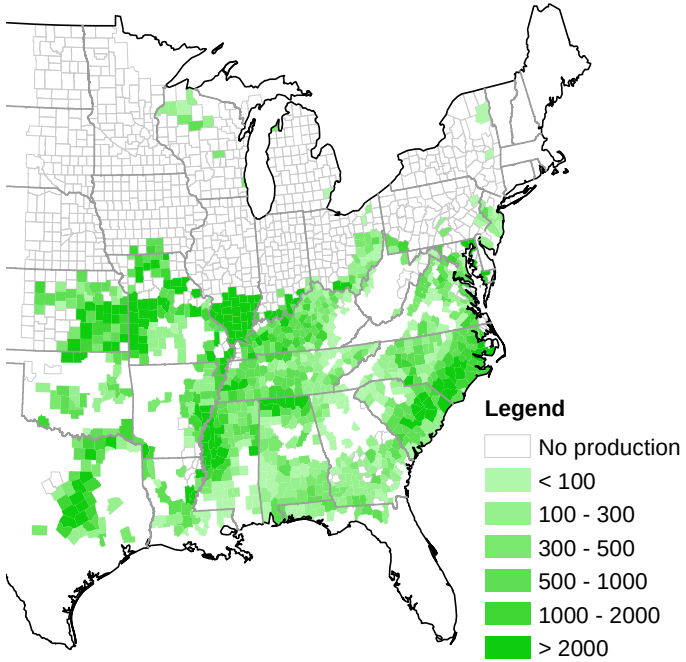


(1.1) Land devoted to miscanthus when there is no credit constraint

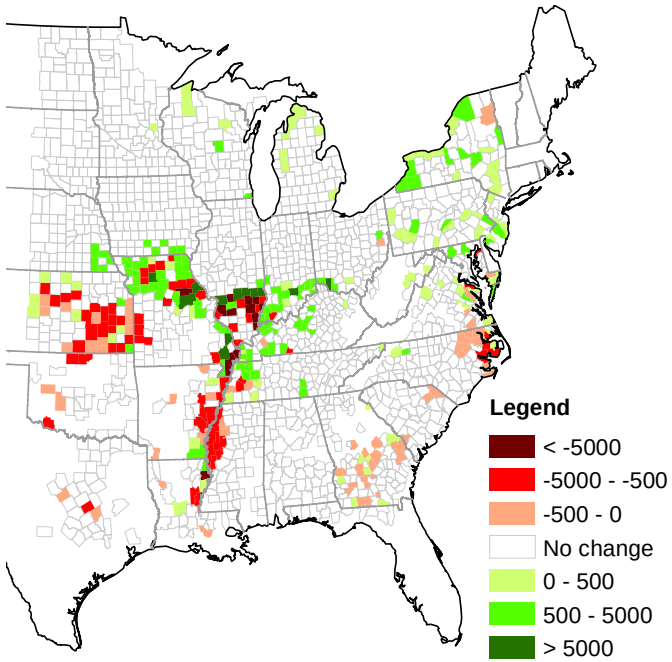


(1.2) Change of energy crop acreage after credit constraint is imposed

Figure 1. Land devoted to miscanthus when energy crop insurance is available (unit: acres)



(2.1) Land devoted to miscanthus when there is no credit constraint



(2.2) Change of energy crop acreage after credit constraint is imposed

Figure 2. Land devoted to miscanthus when energy crop insurance is not available (unit: acres)