Crop Insurance for Energy Grasses

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Abstract

This study compares the efficiency of three policy instruments (i.e., crop insurance, establishment cost share, and biomass price subsidy) in promoting energy crop production. The efficiency is measured by energy crop acreage increased due to the policy instrument for a given amount of government expenditure supporting the instrument. Based on a unique dataset of county-level miscanthus yield over 1979-2010 across the rainfed region of the United States, our results show that if there is no credit constraint in financing establishment costs then crop insurance is most efficient and biomass price subsidy is least efficient among the three policy instruments. If there is credit constraint in financing establishment costs, however, then crop insurance is more (respectively, less) efficient than establishment cost share for small (respectively, large) expenditure. Geographical distributions of energy crop acreage under different policy instruments are studied as well.

Keywords: crop insurance, energy crops, establishment costs, miscanthus, yield

JEL codes: Q15, Q16, Q28

Crop Insurance for Energy Grasses

1. Introduction

Increasing concerns about energy security, dependence on non-renewable fossil fuels, and climate change have led to significant policy support for biofuels in recent years. For instance, the Energy Independence and Security Act (EISA) of 2007 mandates that the annual use of biofuel increases to 36 billion gallons by 2022, of which 16 billion gallons must be cellulosic biofuel. Miscanthus (*Miscanthus* × *giganteus*) and switchgrass (*Panicum virgatum*) have long been considered promising cellulosic biofuel crops (Heaton *et al*. 2008). Unlike conventional crops such as corn and soybeans, perennial energy crops are new and unfamiliar and their production involves significant upfront investments (i.e., establishment costs) in establishment which takes one or two years before they yield an income and a 10 to 15-year commitment of land to the crop. Energy crop production exposes farmers to price and yield risks that may differ from conventional crops, to the extent that weather variations affect yields of energy crops differentially and output prices are affected by demand conditions in different markets that may not be correlated. Moreover, the significant amount investments required for perennial energy crop production make credit constraint a relevant issue.

The commercial production of these crops will depend not only on their expected returns relative to that of existing annual crops but also on the riskiness of these crops relative to annual crops. In the presence of crop insurance for conventional crops, farmers will be reluctant to switch to energy crops without similar protection from down-side risks. Although crop insurance programs for energy crops are not being proposed for the 2013 farm bill, insurance programs for energy crops are expected to be critical to induce farmers to convert land from annual crops currently covered by crop insurance, to bioenergy crops as commercial production of cellulosic biofuels commences. Such a program would reduce the risks associated with energy crop production and thus the risk premium that refineries will need to pay farmers to induce production of energy crops. This can reduce the overall cost of cellulosic biofuels and make them more competitive with corn ethanol and gasoline.

Various public interventions have been established or proposed for the biofuel industry targeted towards farmers and refineries. These include a Cellulosic Biofuel Production Tax Credit (CBPTC) that provides blenders a tax credit of $1.01 per gallon of cellulosic biofuels and the Biomass Crop Assistance Program (BCAP) that provides growers with a 75% cost-share of establishment costs, a subsidy of $45 per ton of biomass for two years to cover costs of collection, harvesting, storage and transportation of biomass, and an annual payment up to 15 years for woody biomass and up to 5 years for non-woody biomass. Bioenergy crops have to compete with conventional crops like corn and soybeans that are covered by federally subsidized crop insurance programs that reduce the down-side risks due to weather and market conditions for farmers. In 2011, the USDA had proposed to study the feasibility of providing crop insurance to producers of biofuel feedstock, including crop residues and woody biomass. Provision of energy crop insurance would mitigate their riskiness and the disincentives for allocating land to their production. The effectiveness of targeting federal subsidies towards such an insurance program instead of directly to biofuel and biomass production programs needs to be investigated to design the socially optimal mix of policy interventions that can stimulate the transition to a bio-based economy in the U.S.

The purpose of this study is to provide a comprehensive economic evaluation of a potential crop insurance program for energy grasses. Specifically, we are investigating the following aspects of a potential crop insurance program for energy grasses: 1) comparison of the efficiency between crop insurance and Biomass Crop Assistance Program (BCAP) type policies in 2008 farm bill in enhancing farmers' adoption of energy crops; 2) costs for federal government to support such insurance; and 3) effects on growers' land-use decisions when they are considering whether to plant traditional row crops or energy crops.

Crop insurance coverage is currently available to more than 350 commodities in all 50 states and more than 80% of eligible acres are enrolled in various insurance programs (Babcock 2012). The existence and scope of the federal crop insurance program in U.S. provides a precedent for developing insurance programs to provide comparable risk protection for farmers of bioenergy crops. Previous studies have analysed crop insurance design and the impact of crop insurance for conventional crops on farmers' welfare, land-use decisions, and technology adoption. Several studies have examined the effect of crop insurance on cropping decisions. Goodwin et al. (2004) showed that crop insurance subsidies affected cropping decisions but this effect was not large. This finding is similar to that obtained by more recent studies by Claassen et al. (2011), Rashford et al. (2011), Miao et al. (2012), and Feng et al. (2013) which use finer resolution data and recognize that the value of crop insurance subsidies increase in direct proportion to the output price level. However, under a real option framework that takes switching costs of converting between cropland and grassland into account, Miao et al. (2013) show that the incentivizing effect of crop insurance on native grassland conversion can be very large. Furthermore, Woodard et al. (2012) found that the insurance rules of the Risk Management Agency impeded adoption of skip-row technology.

The impact of crop insurance on farmer welfare has also attracted much attention. For example, by comparing revenue insurance with 1990 deficiency payment program, Hennessy et al. (1997) showed that revenue insurance is more efficient in enhancing farmers' welfare. Their simulations show that revenue insurance with 75% coverage level can provide farmers with about the same benefit but at a fourth of the cost of the deficiency payment program. Coble and Dismukes (2008) also showed that revenue insurance can be more efficient in reducing risk than separate price risk and yield risk instruments.

Unlike previous studies that have analysed the effects of crop insurance for conventional crop choice, this study will examine the effectiveness of crop insurance in inducing the adoption of new crops. A survey of farmers by Fewell et al. (2011) suggests that availability of insurance programs for bioenergy crop production will be a key factor in incentivizing farmers to grow bioenergy crops. We will examine the design of a yield insurance program to induce conversion of land to energy crops. We then examine the implications of federal government subsidies supporting such insurance and compare the efficiency of providing a crop insurance subsidy with that of providing an establishment cost share subsidy or a biomass price subsidy and analyze their implications for farmers' welfare and costs of cellulosic biofuel production.

This study contributes to the literature by studying the effectiveness crop insurance for inducing investment in energy crop production. Based on the yield distributions of energy grasses we can quantify the actuarially fair premiums for yield insurance contracts at different coverage levels. Government budgetary effect of subsidizing crop insurance programs for bioenergy crops is studied. We will examine the effects of different levels of insurance premium subsidy by the government on the profitability of producing energy crops and biofuels at given ethanol prices.

The article proceeds as follows. In the next section we provide a conceptual framework under which key factors that influence growers' land allocation decisions are analyzed. In Section 3 we describe data and simulation approach we employ for this study. Simulation results are presented and discussed in Section 4. Section 5 concludes.

2. Conceptual Framework

Suppose that a grower has L amount of homogenous land that can be devoted to conventional row crops and energy crops. Let x_0 and x_1 denote the quantity of land devoted to conventional crops and energy crops, respectively. Clearly we have $x_0 + x_1 \leq L.$ Also suppose the life-span of the energy crop is T years. Let π_t^0 and π_t^1 denote the profit per acre from growing row crops and energy crops, respectively. Here we assume constant returns to scale. For simplicity we also assume that once a parcel of land is devoted to an energy crop then it will be covered under the energy crop during the energy crop's entire life-cycle, i.e., T years. That is, we assume away the possibility that the grower may abandon the energy crop in a year $t < T$ when market situations are favorable to growing row crops. Given the above assumptions, the grower's problem is to optimally allocate the land between row crop and energy crop so that the discounted expected utility over the T years is maximized. Specifically, we have

(1) $$\max_{x_0, x_1} \sum_{t=1}^{T} \beta^{t-1} \mathrm{E}\big(u(x_0 \pi_t^0 + x_1 \pi_t^1)\big)$$
$$\text{s.t. } x_0 + x_1 = L \text{ and } x_0, x_1 \geq 0,$$

where β is a utility discount factor, and $u(\cdot)$ is an instantaneous utility function such that $u'(\cdot) \geq 0$ and $u''(\cdot) \leq 0.$ In this article we assume that $u(\cdot)$ is a constant absolute risk aversion (CARA) utility function with form $u(\pi_t^i) = 1 - e^{-\alpha \pi_t^i}$.

Let y_t^i and p_t^i are yield and price for crop $i \in \{0,1\}$ in year t, respectively. Here superscript 0 stands for the row crop and 1 for the energy crop. We assume that row crops are covered under revenue crop insurance. Then the indemnity of the row crop in year $t \in \{1,...,T\}$ is,

(2) $$I_t^0 = \max[\phi^0 \mathrm{E}(p_t^0 y_t^0) - p_t^0 y_t^0, 0],$$

where ϕ^0 is the crop insurance coverage level for the row crop, and $\mathrm{E}(\cdot)$ is expectation operator. We further assume that the variable cost and fixed cost of row crop production is v_t^0 and c_t^0, respectively. Therefore, the profit of planting the row crop, π_t^0, can be written as,

(3) $$\pi_t^0 = p_t^0 y_t^0 - v_t^0 y_t^0 - c_t^0 + I_t^0 - (1 - s^0)\mathrm{E}(I_t^0),$$

where $s^0 \in [0,1]$ is premium subsidy rate provided by the government to row crop insurance.

To model the three policy instruments (crop insurance, establishment cost share, and biomass subsidy), extra notations are in order. For energy crop production, let $s^1 \in [0,1]$, $\rho \in [0,1]$, and $p^s \geq 0$ denote insurance premium subsidy rate, establishment cost share endured by the government, and biomass price subsidy to the energy crop, respectively. Since the energy crop production will likely occur under a long-term contract between a grower and a bio-refinery in which biomass price is fixed (Yang *et al*. 2013), in this article we assume that biomass, p_t^1, is a constant over the *T*-year period. Therefore, the indemnity of the energy crop in year *t* is,

$$(4) \qquad I_t^1 = p_t^1 \max[\phi^1 \mathrm{E}(y_t^1) - y_t^1, 0],$$

where ϕ^1 and y_t^1 are the energy crop's insurance coverage level and yield, respectively. Then the profit from planting the energy crop in year *t* is

$$(5) \qquad \pi_t^1 = (p_t^1 + p^s) y_t^1 - v_t^1 y_t^1 - (1-\rho) e_t - c_t^1 + I_t^1 - (1-s^1)\mathrm{E}(I_t^1),$$

where e_t is the energy crop's establishment cost, v_t^1 is variable cost, and c_t^1 is other fixed costs except establishment costs of the energy crop production. Based on equation (5), it is readily checked that $\partial \pi_t^1 / \partial p^s > 0$, $\partial \pi_t^1 / \partial \rho > 0$, and $\partial \pi_t^1 / \partial s^1 > 0$. That is, the three policy instruments will increase grower's profits. We can also show that $\partial \pi_t^1 / \partial p_t^1 > 0$ (see Appendix A), which means that an increase in biomass price will increase energy crop profit even though the premium of crop insurance will increase in biomass price.

Since planting miscanthus involves a large amount of establishment costs, a grower may have difficulty to finance on their own. Therefore, one purpose of this study is to investigate how credit constraint on establishment costs a grower faces may affect the land-use decisions. Equation (5) presents a grower's profit from planting energy crops under credit constraint because the grower finances the establishment cost by herself. Following Bocquého and Jacquet (2010), we model the scenario of without credit constraint by assuming that the grower has access to a loan to pay for the establishment costs in the first two years. Starting from the third year the farmer will pay back the loan with an annuity till the end of year *T*. Assume the annuity to be w. Then the grower's profit from planting miscanthus when there is no credit constraint becomes

(6) $$\pi_t^1 = \begin{cases} (p_t^1 + p^s)y_t^1 - v_t^1 y_t^1 - c_t^1 + I_t^1 - (1-s^1)\mathrm{E}(I_t^1)_t, \text{ if } t \in \{1,2\} \\ (p_t^1 + p^s)y_t^1 - v_t^1 y_t^1 - c_t^1 + I_t^1 - (1-s^1)\mathrm{E}(I_t^1) - w, \text{ if } t \in \{3,...,T\}. \end{cases}$$

The relationship between $e_t,\ t \in \{1,2\}$ and w is

(7) $$(1-\rho)(e_1 + \frac{e_2}{1+r}) = \Big(\frac{1}{1+r} - \frac{1}{(1+r)^{T-1}}\Big)\frac{w}{r},$$

where r is annual interest rate. Equation (9) states that a) the net present value (NPV) of the loan is equal to the NPV of the annuities; and b) the grower only obtain the loan to pay for the establishment costs that are not covered by government subsidy.

The Kuhn-Tucker necessary conditions of problem (1) can be written as

(8) $$\sum_{t=1}^{T}\beta^{t-1}\mathrm{E}\Big(u'((1-x_1^*)\pi_t^0 + x_1^*\pi_t^1)(\pi_t^1 - \pi_t^0)\Big) - \lambda \le 0 \quad (=0 \text{ if } x_1^* > 0) \text{ and}$$
$$\lambda \ge 0 \quad (=0 \text{ if } x_1^* < L),$$

where λ is the Lagrange multiplier. For an interior solution (i.e., $0 < x_1^* < L$) the necessary conditions can be simplified as

(9) $$\sum_{t=1}^{T}\beta^{t-1}\mathrm{E}\Big(u'((1-x_1^*)\pi_t^0 + x_1^*\pi_t^1)(\pi_t^1 - \pi_t^0)\Big) = 0$$

Given the assumption of CARA utility function, it is readily checked that $\partial x_1^* / \partial \rho > 0$ and $\partial x_1^* / \partial s^1 > 0$. These two inequalities state that both increasing establishment cost share and increasing premium subsidy rate of energy crop insurance will enlarge the optimal acreage of energy crop. Without further information regarding the utility function and the joint distributions of crop yields and row crop price, however, we cannot identify the signs of $\partial x_1^* / \partial p_t^1$ and $\partial x_1^* / \partial p^s$. To see this, by implicit function theorem we have

$$\text{(10)} \qquad \frac{\partial x_1^*}{\partial p_t^1} = \frac{\sum_{t=1}^{T} \beta^{t-1} \mathrm{E}\Big(u''(\Pi)(\pi_t^1 - \pi_t^0) x_1^* \frac{\partial \pi_t^1}{\partial p_t^1}\Big) + \sum_{t=1}^{T} \beta^{t-1} \mathrm{E}\Big(u'(\Pi) \frac{\partial \pi_t^1}{\partial p_t^1}\Big)}{-\sum_{t=1}^{T} \beta^{t-1} \mathrm{E}\Big(u''(\Pi)(\pi_t^1 - \pi_t^0)^2\Big)},$$

where we define $\Pi \equiv (1 - x_1^*)\pi_t^0 + x_1^* \pi_t^1$ to save notation. The sign of $\partial x_1^* / \partial p_t^1$ is the same as the sign of the numerator of equation (10) because the denominator is positive by $u''(\cdot) < 0$ and $(\pi_t^1 - \pi_t^0)^2 > 0$. The second term in the numerator of equation (10) is positive. However, without further information on the distributions of crop yields and row crop prices, we cannot decide the sign of the first term in the numerator. Since $u''(\cdot) < 0$, $x_1^* > 0$, and $\partial \pi_t^1 / \partial p_t^1 > 0$, we conjecture that a) when $\pi_t^1 - \pi_t^0$ is very small or even negative (e.g, when p_t^1 is very low), then $\partial x_1^* / \partial p_t^1$ is more likely to be positive, and b) when $\pi_t^1 - \pi_t^0$ is large (e.g., when p_t^1 is very high) then $\partial x_1^* / \partial p_t^1$ is more likely to be negative. In our simulation we find evidence supporting this conjecture. Similar analysis about equation (10) applies for $\partial x_1^* / \partial p^s$. If $u''(\cdot) = 0$, i.e., the grower is risk neutral, then we have $\partial x_1^* / \partial p_t^1 \geq 0$ and $\partial x_1^* / \partial p^s \geq 0$, which means that an increase in biomass price or biomass price subsidy will increase, at least weakly, the optimal acreage of energy crop. In the next section we employ simulation to further investigate how the risk aversion parameter and the three policy instruments affect the growers' land allocation decisions.

3. Data and Simulation Approach

3.1. Data

Our numerical analysis is based on historical data on crop yields and prices of conventional crops and simulated data for yields of energy crops and projected price of biomass to estimate crop-specific yield and price distributions. Yields of conventional crops (corn and soybeans in this study) over 1979-2010 and across the rain-fed area of U.S. have been obtained from National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture (USDA) (http://www.nass.usda.gov/Quick_Stats/index.php).

In the absence of observed data from commercial production of miscanthus in the U.S., 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, that 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, BIOCRO, to simulate the yield of miscanthus in the United States. Incorporating the biochemical, physiological, and environmental biophysical mechanisms that affect plant growth, BIOCRO simulates hourly leaf-level photosynthesis and stomatal conductance and scales up to the crop level using a multi-layer canopy architecture. The predictive ability of the model was tested with 30 previously published studies and the mean bias is only at 0.62 metric tonne/ha. BIOCRO was used to simulate yields over a 32 year period using climate and soil data for 1979-2010, on a 32 by 32 km grid for the continental US. Annual yield estimates for miscanthus in the rain-fed area were obtained for each grid over 1979-2010 period and were aggregated to the county-level.

Figure SM1 in the Supplemental Materials (SM) of this article paper shows maps of the county-level average yield of these two energy crops and of corn and soybeans. Note that in Figure SM1 the scales used to depict yields differ across the maps to illustrate spatial variation in yields for each crop. The spatial variability in the yields suggests that the economic benefits of switching from corn/soybeans to miscanthus will differ across locations.

Figure SM2 in SM shows the variability in these yields with the 1979-2010 climatic conditions by calculating the coefficient of variation (defined as the ratio of standard deviation of yield to mean yield) for each county in the rain-fed area of the U.S. Higher values indicate greater variability in yields. The figure shows that miscanthus yield is more variable in the northern region and the Great Plains region while corn is relatively more risky in the Atlantic states.

State-level received prices for corn and soybean over 1979-2010 are obtained from NASS as well. Production costs of miscanthus in 30 states of the rain-fed US has been well documented by Khanna *et al*. (2008) and Jain *et al*. (2010). Other techno-economic information including costs of biofuel production, conversion efficiency of biomass to biofuel, costs of transportation of biomass are obtained from related literature (see Huang *et al*. 2013 for a review on the literature).

As we have discussed under our conceptual framework, biomass price will likely be fixed under production contracts between growers and bio-refineries. Therefore, in our simulation we consider two scenarios regarding biomass price: a low price scenario under which the biomass price is $48/Mg and a high price scenario under which the biomass price is $81/Mg. Here $48/Mg and $81/Mg are corresponding to crude oil prices at $100/barrel and $120/barrel, respectively. In this article we assume that ethanol price and biomass price are determined by crude oil price. We utilize the conversion parameters in Tyner and Taheripour (2007) and Jain et al. (2010) to convert crude oil prices into ethanol prices and then to biomass prices.

3.2. Joint yield-price distributions

To calculate the expected profit from growing the row crops and miscanthus requires joint yield-price distributions. Copula approach is employed to obtain the joint distributions. Because of their flexibility, copula approach is becoming increasingly popular when modeling joint distributions (Yan 2007). Copula approach can be implemented by the Inference Function for Margins (IFM) method, which estimates marginal distributions first and then, by taking these marginals as given, estimates the copula. For a crop, we first select the best fitting yield distribution by Kolmogorov-Smirnov test from eight distributions that are often used to model yield distributions. These eight distributions are: Beta, Gamma, Logistic, Lognormal, Normal, Reverse gamma, Reverse lognormal, and Weibull. We then use the best fitting yield distribution as the marginal yield distributions in the copula estimation. Price marginal distributions for conventional crops are obtained by estimating a normal distribution for the detrended state-level received prices. Once we obtain the joint distributions, yield-price joint draws from the distributions can be made, on which the simulation is based upon. For procedures of performing copula estimation and make random draws from the estimated distribution, we refer readers to Miao, Hennessy, and Feng (2012).

3.3. Efficiency Comparison between Policy Instruments

We define the efficiency of a policy instrument to be the energy crop acreage increased by the instrument for a given amount of government expenditure supporting the policy instrument. As we have discussed in Introduction, in this study we focus on three policy instruments: subsidized crop insurance, establishment cost share, and a direct biomass price subsidy. To compare the efficiency, we first map the relationship between energy crop acreage and the government expenditure under a policy instrument. Then we compare the acreage across all three instruments for a given amount of expenditure and determine which instrument is more efficient than the others.

Here we take subsidized crop insurance as an example to illustrate how we obtain the acreage-expenditure relationship for a policy instrument. Similar procedures apply for obtaining the acreage-expenditure relationship for establishment cost share and biomass price subsidy. For simplicity we assume that government expenditure under a subsidized crop insurance program only consists of premium subsidies. We do not consider the administration and operating (A&O) costs that is usually a component of government expenditure supporting crop insurance.[1] Under a given premium subsidy rate, we solve the grower's maximization problem and obtain the optimal acreage allocated to energy crop and the government expenditure in the form of premium subsidies. Therefore, we have one pair of acreage-expenditure values. To obtain the acreage-expenditure relationship under energy crop insurance, we vary premium subsidy rate from 0 to 100% and obtain many pairs of acreage-expenditure values from which we can construct the acreage-expenditure relationship.

4. Results

We specify four key scenarios in our simulation. They are: 1) the baseline scenario under which no policy intervention is in presence; 2) energy crop insurance scenario under which only crop insurance is considered and the insurance coverage level, ϕ^1, is assumed to be 75%; 3) establishment cost share scenario under which only the policy instrument establishment cost share is considered; and 4) biomass price subsidy scenario under which only the policy instrument of biomass price subsidy is considered. Table 1 presents a specific set of simulation results regarding energy crop acreage and expenditure under each scenario where insurance premium subsidy rate, s^1, is assumed to be 55%, establishment cost share, ρ, is assumed to be 75%, and biomass price subsidy rate, p^s, is assumed to be \$5/Mg.

4.1. Acreage and Expenditure under Each Scenario

From Table 1 we can see that when there is credit constraint and when biomass price is at \$48/Mg, then the acreage devoted to miscanthus in the studied area under the baseline scenario is about 1.5 million acres. To put the acreage number in perspective, consider a

[1] Government's total A&O costs for crop insurance may not change very much when energy crops are covered by crop insurance. This is because a) A&O cost is proportional to premium (Shield 2012), and b) an increase in energy crop acreage implies a decrease in row crop acreage and hence the total premium may not change very much.

miscanthus yield at 7.2Mg/acre (the sample mean of our data) and a conversion rate at 87.2 gallon per Mg of biomass (see Jain et al. (2010)). Then the 1.5 million acres devoted to miscanthus production will generate 0.94 billion gallons of cellulosic ethanol per year. Relaxing credit constraint will significantly increase miscanthus acreage. For example, when biomass price is $48/Mg, the miscanthus acreage under each scenario except establishment cost share scenario is about 10 times larger than that when there is credit constraint. The effect of credit constraint on energy crop acreage is smaller under the establishment cost share scenario. This is intuitive because under that scenario the establishment cost is subsidized. The effect of biomass price on miscanthus acreage is also significant. When biomass price increases from $48/Mg to $81/Mg, then miscanthus acreage under the baseline scenario with credit constraint increases from 1.5 million acres to 24.5 million acres.

Regarding government expenditure, from Table 1 we can see that the expenditure under increases when biomass price increases. This is because the expenditure under the three policy instruments is proportional to the acreage that increases when biomass price jumps from $48/Mg to $81/Mg. For the same reason, the expenditure under each policy instrument increases as credit constraint is relaxed.

Figures 1 to 4 include maps of county-level miscanthus acreage under each scenario and different assumptions of biomass price and credit constraint. These four figures show that when biomass price is low (i.e., $48/Mg), then under the baseline scenario the acreage of miscanthus is mainly located in south-eastern states, such as Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi. However, when biomass price is high (i.e., $81/Mg), then a few Midwestern states, such as Wisconsin, Illinois, and Nebraska, will see an increased acreage of miscanthus. Especially, when biomass price is high and when there is no credit constraint, Midwestern states become the major production region for miscanthus even under the baseline scenario (see Figure 4). From the maps in Figures 1 to 4 we can see that a 75% establishment cost share will make the Midwestern states a major production region of miscanthus even if biomass price is low and if growers are facing credit constraint. This is because the 75% establishment cost share is a large support to miscanthus growers given the magnitude of the establishment cost of miscanthus production. When biomass price is low, then a $5/Mg biomass price subsidy can double miscanthus acreage than that under the baseline scenario. However, the effect of biomass price subsidy on miscanthus acreage becomes weaker when biomass price is high.

4.2. Efficiency of the Three Policy Instruments

Figures 1 to 4 and Table 1 show that the 75% establishment cost share has the largest effect on increasing miscanthus acreage. However, this does not mean that establishment cost share is the more efficient than energy crop insurance or biomass price subsidy. To compare the efficiency between these three policy instruments, we need to compare miscanthus acreage for a given amount of government expenditure under each instrument. Figures 5 and 6 depict the relationship between miscanthus acreage and program expenditure for each instrument, under credit constraint and under no credit constraint, respectively. In Figures 5 and 6, we consider four cases of risk aversion and biomass price combinations. The low and high risk aversion parameters are corresponding to risk premiums at 0.1 and 0.2, respectively. Following Babcock *et al*. (1993), a farmer with risk premium equal to 0.1 is willing to pay 10% of the standard deviation of farm revenue to eliminate income risk. The low and high biomass prices are $48/Mg and $81/Mg, respectively.

From Figures 5 and 6 we can see that biomass price subsidy is always dominated by establishment cost share and energy crop insurance. When there is credit constraint, then energy crop insurance first dominates, and then is dominated by, establishment cost share as expenditure increases (Figure 5). When there is no credit constraint, then crop insurance is always the most efficient policy instrument while biomass price subsidy is the least efficient one (Figure 6). Price subsidy is dominated by crop insurance and establishment cost share because, unlike biomass price subsidy, crop insurance and establishment cost share provide support to growers when they need the support most. Specifically, crop insurance provides growers with indemnities when yield of miscanthus is lower than a guaranteed level. Establishment cost share, on the other hand, provides support during the establishment period when there is no harvest of biomass and hence the net return from miscanthus is negative. That is, a subsidy in establishment cost provides financial support when net returns form miscanthus is negative. Therefore, such subsidy is very valuable. Biomass price subsidy, however, provides support that is proportional to biomass yield. The total price subsidy a farmer obtains is larger in a “good year” (a year with high yield) and smaller in a “bad year” (a year with low yield). Therefore, biomass price subsidy does not have the effect of smoothing returns across years that both crop insurance and establishment cost share have. As a result, crop insurance and establishment cost share are more efficient than biomass price subsidy.

The reason that crop insurance first dominates and then is dominated by establishment cost share as expenditure increases under credit constraint is as follows. Notice that even there is no premium subsidy and hence no government expenditure, crop insurance still has the effect of smoothing returns across years over miscanthus’ lifespan. However, establishment cost share does not have this property. It affects growers’ land allocation decision only when it provides payment to the growers. As the establishment cost share payment becomes larger, the effect of this payment on land allocation decision increases. When growers can have access to a loan that finances the establishment costs, then the effect of the establishment cost share on smoothing returns becomes less important because the loan has the same effect. This is why when there is no credit constraint then establishment cost share is strictly dominated by crop insurance.

4.3. Marginal Effects

To investigate how a change in the magnitude of the three policy instruments and in grower's risk attitude affects the share of energy crop acreage for a given biomass price, we simulate miscanthus acreage share for each county under 625 combinations of risk premium $\theta \in \Theta \equiv$ {0.1, 0.2, 0.3, 0.4, 0.5}, crop insurance premium subsidy rate $s^1 \in S \equiv$ {45%, 50%, 55%, 60%, 65%}, share of establishment cost $\rho \in R \equiv$ {10%, 20%, 30%, 40%, 50%}, and biomass price subsidy rate $p^s \in \Omega \equiv$ {\$5/Mg, \$10/Mg, \$15/Mg, \$20/Mg, \$25/Mg} for a given biomass price $p_t^1 \in P \equiv$ {\$48/Mg, \$81/Mg} and for a given credit constraint situation $\delta \in \Delta \equiv$ {credit constraint, no credit constraint}. Parameter vector $(s^1, \rho, p^s) \in S \times R \times \Omega$ can be viewed a vector of policy instrument parameters and vector $(p_t^1, \delta) \in P \times \Delta$ can be viewed as a vector of market condition parameters. It is readily checked that set $\Theta \times S \times R \times \Omega$ has 625 elements. In total, for each county we have 2,500 values of miscanthus acreage share because set $\Theta \times S \times R \times \Omega \times P \times \Delta$ has 2,500 elements.

Under each vector of market condition parameters, $(p_t^1, \delta) \in P \times \Delta$, we first fix a risk premium parameter or a policy instrument parameter, then we calculate the optimal miscanthus acreage share under each combinations of the remaining parameters for each county and take simple average of these acreage shares across all counties. For example, the average energy crop share when 1) biomass price is \$48/Mg, 2) credit constraint is in presence, and 3) risk premium is 0.1 is calculated as the simple average of 125 share values that are corresponding to 125 vectors of policy instrument parameters, $(s^1, \rho, p^s) \in S \times R \times \Omega$ while setting biomass price at $p_t^1 =$ \$48/Mg, risk premium at $\theta = 0.1$, and credit constraint is in presence. Table 2 summarizes the calculation results. The value of land share of miscanthus in Table 2 should be explained in the following way. Here we use 9.15, the number of land share corresponding to risk premium at 0.1 in the upper-left panel of Table 2, as an example. This number means that the simple average of land share of miscanthus across all counties is 9.15% when 1) the biomass price is $48/Mg, 2) growers face credit constraint, 3) the risk premium is 0.1, and 4) the parameters of the three policy instruments, $(s^1, \rho, p^s) \in S \times R \times \Omega$, take values from their 125 combinations.

From Table 2 we can see that when market situation and policy instrument parameters take values described above, then the average land share of miscanthus decreases as risk premium increases. This may indicate that miscanthus is more risky than row crops (corn and soybean in this study), which is consistent what we have shown in Figure SM2. As we have shown in the conceptual framework, an increase in crop insurance subsidy rate or in establishment cost share increases the land share. Corresponding to the findings in the conceptual framework, from Table 2 we do observe that an increase in biomass price subsidy can either increase or decrease the optimal land share of miscanthus. When biomass price is $48/Mg and when there is no credit constraint, then the land share first increases and then decreases as biomass price subsidy increases from $5/Mg to $25/Mg. When biomass is $81/Mg and when there is no credit constraint, we observe that the land share decreases as biomass price subsidy increases from $5/Mg to $25/Mg. One reason for the fact that higher biomass price subsidy may decrease miscanthus land share is that the increase in price increases the variance of miscanthus' profit and hence decreases risk averse growers' willingness to plant miscanthus.

5. Conclusions

In this paper we develop a conceptual framework of growers' optimal land allocation decisions between row crops and energy crops. Based on the county-level yield data of corn, soybean and miscanthus, we simulate and compare the efficiency of crop insurance, establishment cost share, and biomass price subsidy in terms of incentivizing growers' adoption of energy crops. We find that when there is no credit constraint, then crop insurance is the most efficient and biomass price subsidy is the least efficient among the three policy instruments. However, when growers face credit constraint on financing establishment costs, then crop insurance is more efficient than establishment cost share for relatively small expenditure but is less efficient than establishment cost share for relatively large expenditure. We also find that under certain conditions an increase in biomass price subsidy may not necessarily increase the optimal miscanthus acreage.

Geographical distributions of miscanthus acreage under various scenarios are discussed. When there are no policy interventions and when biomass price is low, then the southeastern United States will be the major production region of miscanthus. When there is no credit constraint and when biomass price is high, however, then the Midwestern states will become the major region for miscanthus production. The policy instruments we discussed in this study generally will increase miscanthus acreage. When compared with southeastern states, Midwestern states have larger potential to respond to incentives from the policies.

Appendix A

In this appendix we show that $\partial \pi_t^1 / \partial p_t^1 > 0$ where π_t^1 is defined in equation (5). By equation (4) we have

(A1) $$\frac{\partial \pi_t^1}{\partial p_t^1} = y_t^1 + \frac{\partial I_t^1}{\partial p_t^1} - (1 - s^1)\frac{\partial \mathrm{E}(I_t^1)}{\partial p_t^1}.$$

Assume the cumulative distribution function (CDF) of energy crop yield is $G(y_t^1)$ with support $[0, \infty)$. Then we have

(A2) $$\frac{\partial I_t^1}{\partial p_t^1} = \max[\phi^1 \mathrm{E}(y_t^1) - y_t^1, 0], \text{ and}$$

(A3) $$\frac{\partial \mathrm{E}(I_t^1)}{\partial p_t^1} = \frac{\partial \int_0^\infty I_t^1 dG(y_t^1)}{\partial p_t^1} = \int_0^\infty \frac{\partial I_t^1}{\partial p_t^1} dG(y_t^1) = \int_0^\infty \max[\phi^1 \mathrm{E}(y_t^1) - y_t^1, 0] dG(y_t^1)$$
$$= \int_0^{\phi^1 \mathrm{E}(y_t^1)} (\phi^1 \mathrm{E}(y_t^1) - y_t^1) dG(y_t^1).$$

Plugging equations (A2) and (A3) into equation (A1) we can obtain,

(A4)
$$\frac{\partial \pi_t^1}{\partial p_t^1} = y_t^1 + \max[\phi^1 \mathrm{E}(y_t^1) - y_t^1, 0] - (1 - s^1) \int_0^{\phi^1 \mathrm{E}(y_t^1)} (\phi^1 \mathrm{E}(y_t^1) - y_t^1) dG(y_t^1)$$
$$= \max[\phi^1 \mathrm{E}(y_t^1), y_t^1] - (1 - s^1) \int_0^{\phi^1 \mathrm{E}(y_t^1)} \phi^1 \mathrm{E}(y_t^1) dG(y_t^1) + (1 - s^1) \int_0^{\phi^1 \mathrm{E}(y_t^1)} y_t^1 dG(y_t^1)$$
$$= \max[\phi^1 \mathrm{E}(y_t^1), y_t^1] - (1 - s^1) \phi^1 \mathrm{E}(y_t^1) G(\phi^1 \mathrm{E}(y_t^1)) + (1 - s^1) \int_0^{\phi^1 \mathrm{E}(y_t^1)} y_t^1 dG(y_t^1)$$
$$> 0, \text{ by } s^1 \in [0,1] \text{ and } G(\phi^1 \mathrm{E}(y_t^1)) < 1.$$

References

Babcock, B.A. 2012. "The Politics and Economics of the U.S. Crop Insurance Program." in J.S. Graff Zivin and J.M. Perloff eds. The Intended and Unintended Effects of U.S. Agricultural and Biotechnology Policies. University of Chicago Press.

Babcock, B.A., K.E. Choi, and E. Feinerman. 1993. "Risk and Probability Premiums for CARA Utility Functions." Journal of Agricultural and Resource Economics, 18(1):17-24.

Claassen, R., J.C. Cooper, and F. Carriazo. 2011. "Crop Insurance, Disaster Payments, and Land Use Change: The Effect of Sodsaver on Incentives for Grassland Conversion." Journal of Agricultural and Applied Economics, 43(2):195-211.

Clifton-Brown, J.C., P. Stampfl, M.B. Jones. 2004. "Miscanthus biomass production for energy in Europe and its potential contribution to decreasing fossil fuel carbon emissions." Global Change Biology. 10: 509–18.

Coble, K.H., R. Dismukes. 2008. "Distributional and Risk Reduction Effects of Commodity Revenue Program Design." Review of Agricultural Economics. 30(3):543-53.

Goodwin, B.K., M.L. Vandeveer, and J.L. Deal. 2004. “An Empirical Analysis of Acreage Effects of Participation in the Federal Crop Insurance Program.” American Journal of Agricultural Economics. 86(4):1058-1077.

Feng, Hongli, David A. Hennessy, and Ruiqing Miao. 2013. “The Effects of Government Payments on Native Grassland Conversion, the CRP, and Corn Acreage Changes in the Dakotas.” American Journal of Agricultural Economics. 95(2): 412-418.

Fewell, J., J. Bergtold, and J. Williams. 2011. “Farmers’ Willingness to Grow Switchgrass as a Cellulosic Bioenergy Crop: A Stated Choice Approach.” Paper presented at the 2011 Joint Annual Meeting of the Canadian Agricultural Economics Society & Western Agricultural Economics Association, Banff, Alberta, Canada.

Heaton, E., F. Dohleman, and S. Long. 2008. “Meeting US biofuel goals with less land: The potential of miscanthus.” *Global Change Biology*. 14:2000-2014.

Hennessy, D.A., B.A. Babcock, and D.J. Hayes. 1997. “Budgetary and Producer Welfare Effects of Revenue Insurance.” American Journal of Agricultural Economics. 79(3): 1024-34.

Huang, H. M. Khanna, M, H. Onal and X.Chen. 2013. “Stacking Low Carbon Policies on the Renewable Fuel Standard: Economic and Greenhouse Gas Implications.” Energy Policy. 56: 5-15.

Jain, A. K., M. Khanna, M. Erickson, and H. Huang. 2010. “An Integrated Biogeochemical and Economic Analysis of Bioenergy Crops in the Midwestern United States.” Global Change Biology Bioenergy. 2: 217-234.

Khanna, M., B. Dhungana, and J. Clifton-Brown. 2008. “Costs of Producing Miscanthus and Switchgrass for Bioenergy in Illinois.” Biomass and Bioenergy. 32:482-93.

Kiniry, J.R., J.R. Williams, P.W. Gassman, P. Debaeke. 1992. “A general process-oriented model for two competing plant species.Transactions of the ASAE, 35, 801–10.

Kiniry, J.R., K.A. Cassida, and M.A. Hussey et al. 2005. “Switchgrass simulation by the ALMANAC model at diverse sites in the southern U.S.” Biomass and Bioenergy, 29, 419–25.

Kiniry, J.R., M.A. Sanderson, J.R. Williams. 1996. “Simulating Alamo switchgrass with the ALMANAC model.” Agronomy Journal. 88: 602–06.

McLaughlin, S.B., J.R. Kiniry, C. Taliaferro, D. Ugarte. 2006. “Projecting yield and utilization potential of switchgrass as an energy crop.” Advances in Agronomy. 90: 267–97.

Miao, Ruiqing, Hongli Feng, and David A. Hennessy. 2012. “The Effect of Crop Insurance Subsidies and Sodsaver on Land Use Change.” Center for Agricultural and Rural Development, Iowa State University. Working Paper 12-WP 530.

Miao, Ruiqing, David A. Hennessy, and Hongli Feng. 2013. “Native Grassland Conversion: The Roles of Risk Intervention and Switching Costs.” Center for Agricultural and Rural Development, Iowa State University. Working Paper 13-WP 536.

Miguez, F.E., M. Maughan, G.A. Bollero, and S.P. Long. 2012. “Modeling spatial and dynamic variation in growth, yield, and yield stability of the bioenergy crops Miscanthus × giganteus and Panicum virgatum across the conterminous United States.” Global Change Biology: Bioenergy. 4(5):509-520.

Rashford, B.S., J.A. Walker, and C.T. Bastian. 2011. “Economics of Grassland Conversion to Cropland in the Prairie Pothole Region.” Conservation Biology, 25(2):276-284.

Shields, D.A. 2012. “Federal Crop Insurance: Background.” Congressional Research Service. CRS Report for Congress, December 6.

Tyner, W.E. and F. Taheripour. 2007. “Future Biofuels Policy Alternatives.” Working paper. Department of Agricultural Economics, Purdue University.

Woodard, J.D., A.D. Pavlista, G.D. Schnitkey, P.A. Burgener, and K.A. Ward. 2012. “Government Insurance Program Design, Incentive Effects, and Technology Adoption: The Case of Skip-Row Crop Insurance.” American Journal of Agricultural Economics. 94(4): 823-37.

Yan, J. 2007. “Enjoy the Joy of Copulas: with a Package copula.” Journal of Statistical Software. 21(4):1-21.

Yang, X., N.D. Paulson, and M. Khanna. 2012. “Optimal Contracts to Induce Biomass Production under Risk”. Paper presented at the Agricultural & Applied Economics Association’s 2012 AAEA&NAREA Joint Annual Meeting, Seattle, Washington, August 12-14, 2012.

Table 1. Acres Devoted to Energy Crops and Government Expenditures under Different Policy Instruments
(units: both acres and expenditure are in 1,000)

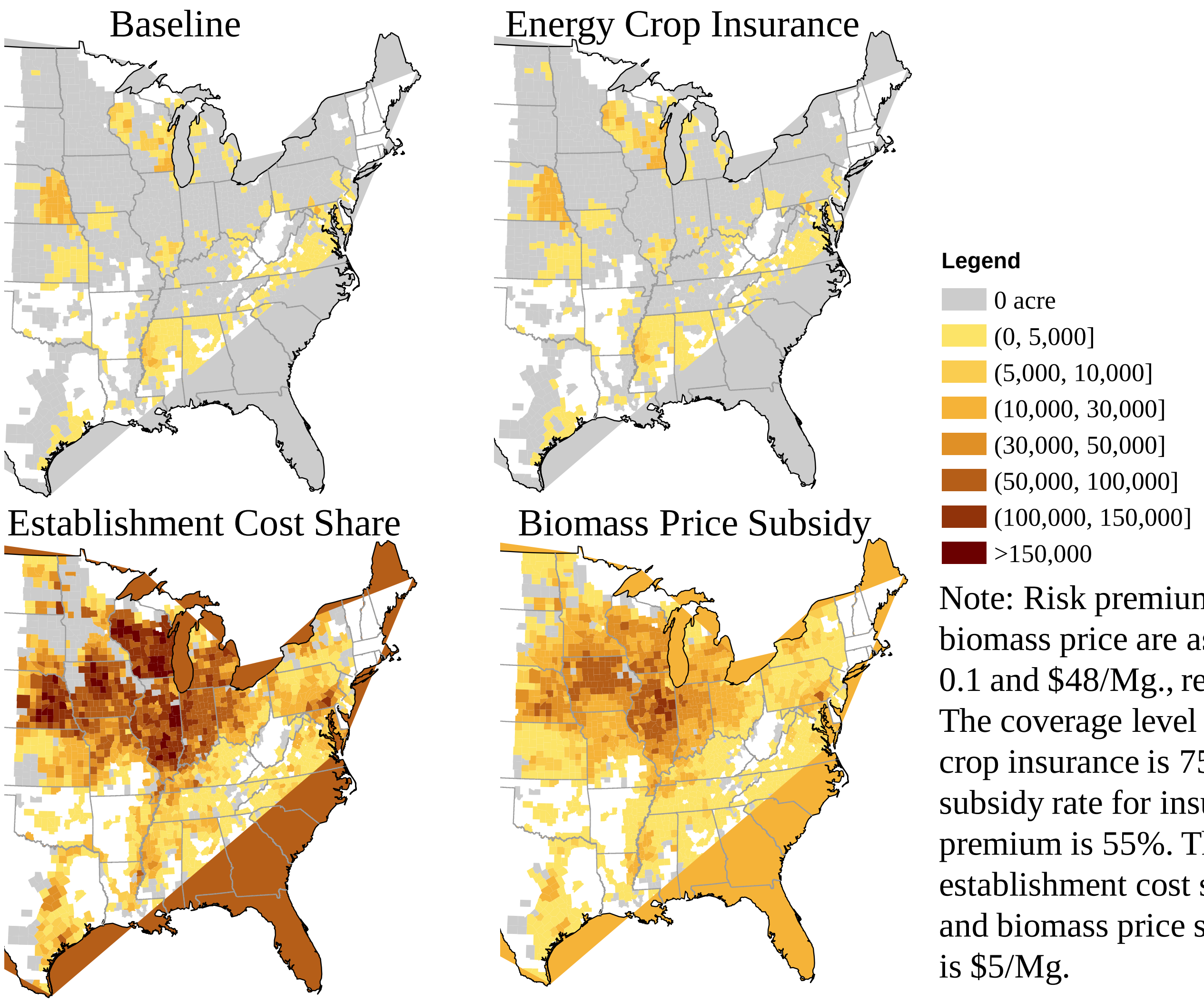
	With Credit Constraint				Without Credit Constraint			
	Biomass Price = $48/Mg.		Biomass Price = $81/Mg.		Biomass Price = $48/Mg.		Biomass Price = $81/Mg.	
	acres	expenditure	acres	expenditure	acres	expenditure	acres	expenditure
Baseline Scenario	1,517	0	24,493	0	15,316	0	105,626	0
Energy Crop Insurance	1,776	118,694	25,597	2,851,573	19,808	1,465,437	108,331	12,864,001
Establishment Cost Share	55,345	56,130,664	103,315	105,047,362	88,872	90,221,111	110,174	112,057,878
Biomass Price Subsidy	4,063	1,937,697	26,515	12,363,869	42,768	20,400,908	106,906	48,984,829

Note: Expenditures are the total amount of expenditures over 15 years (i.e., a life-circle of miscanthus). Energy crop insurance is with 75% of coverage level and 55% premium subsidy rate. Establishment cost share rate is 75%. Biomass price subsidy rate is $5/Mg. Here Mg. stands for million gram.

Table 2. Share of Cropland Devoted to Miscanthus under Various Model Specifications

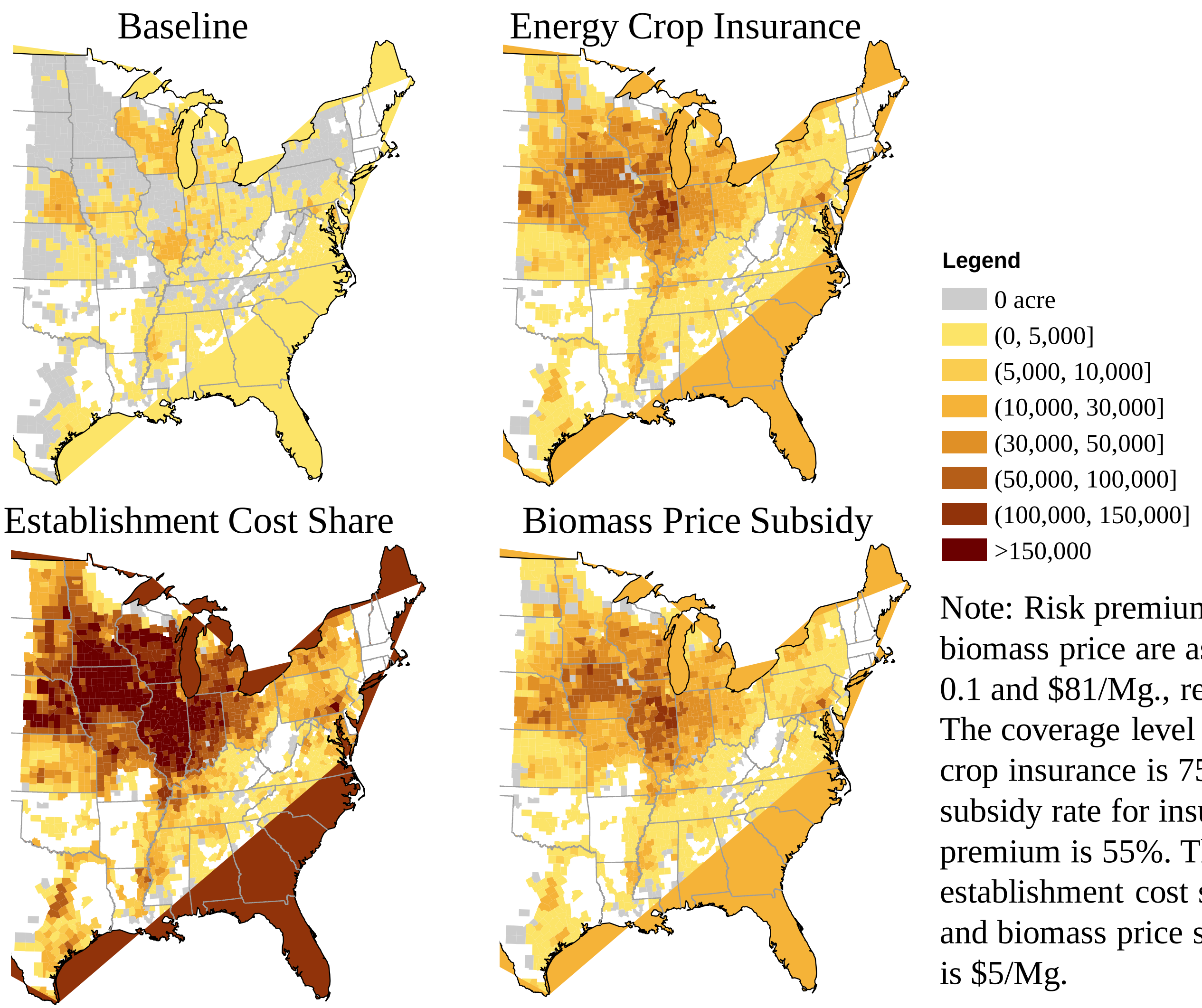
		Biomass Price = $48/Mg.					**Biomass Price = $81/Mg.**				
with credit constraint	Risk Premium	0.1	0.2	0.3	0.4	0.5	0.1	0.2	0.3	0.4	0.5
	Land Share of Miscanthus (%)	9.15	4.84	3.34	2.54	2.01	14.71	7.41	4.91	3.59	2.74
	Crop Insurance Premium Subsidy (%)	45	50	55	60	65	45	50	55	60	65
	Land Share of Miscanthus (%)	4.35	4.37	4.38	4.39	4.40	6.66	6.666	6.673	6.68	6.69
	Share of Establishment Cost (%)	10	20	30	40	50	10	20	30	40	50
	Land Share of Miscanthus (%)	2.44	3.11	4.00	5.27	7.08	4.63	5.38	6.34	7.63	9.39
	Biomass Price Subsidy ($)	5	10	15	20	25	5	10	15	20	25
	Land Share of Miscanthus (%)	2.82	3.80	4.56	5.14	5.58	6.39	6.57	6.71	6.81	6.89
without credit constraint	Risk Premium	0.1	0.2	0.3	0.4	0.5	0.1	0.2	0.3	0.4	0.5
	Land Share of Miscanthus (%)	32.69	32.36	30.76	26.74	23.08	35.50	35.45	30.55	24.26	19.83
	Crop Insurance Premium Subsidy (%)	45	50	55	60	65	45	50	55	60	65
	Land Share of Miscanthus (%)	29.01	29.07	29.13	29.18	29.24	29.08	29.10	29.12	29.13	29.15
	Share of Establishment Cost (%)	10	20	30	40	50	10	20	30	40	50
	Land Share of Miscanthus (%)	26.05	27.40	28.87	30.80	32.49	27.84	28.08	28.68	30.02	30.97
	Biomass Price Subsidy ($)	5	10	15	20	25	5	10	15	20	25
	Land Share of Miscanthus (%)	25.23	28.94	30.29	30.65	30.52	30.05	29.59	29.12	28.65	28.17

Note: Biomass price is in 2006 dollars. Mg. stands for million gram.



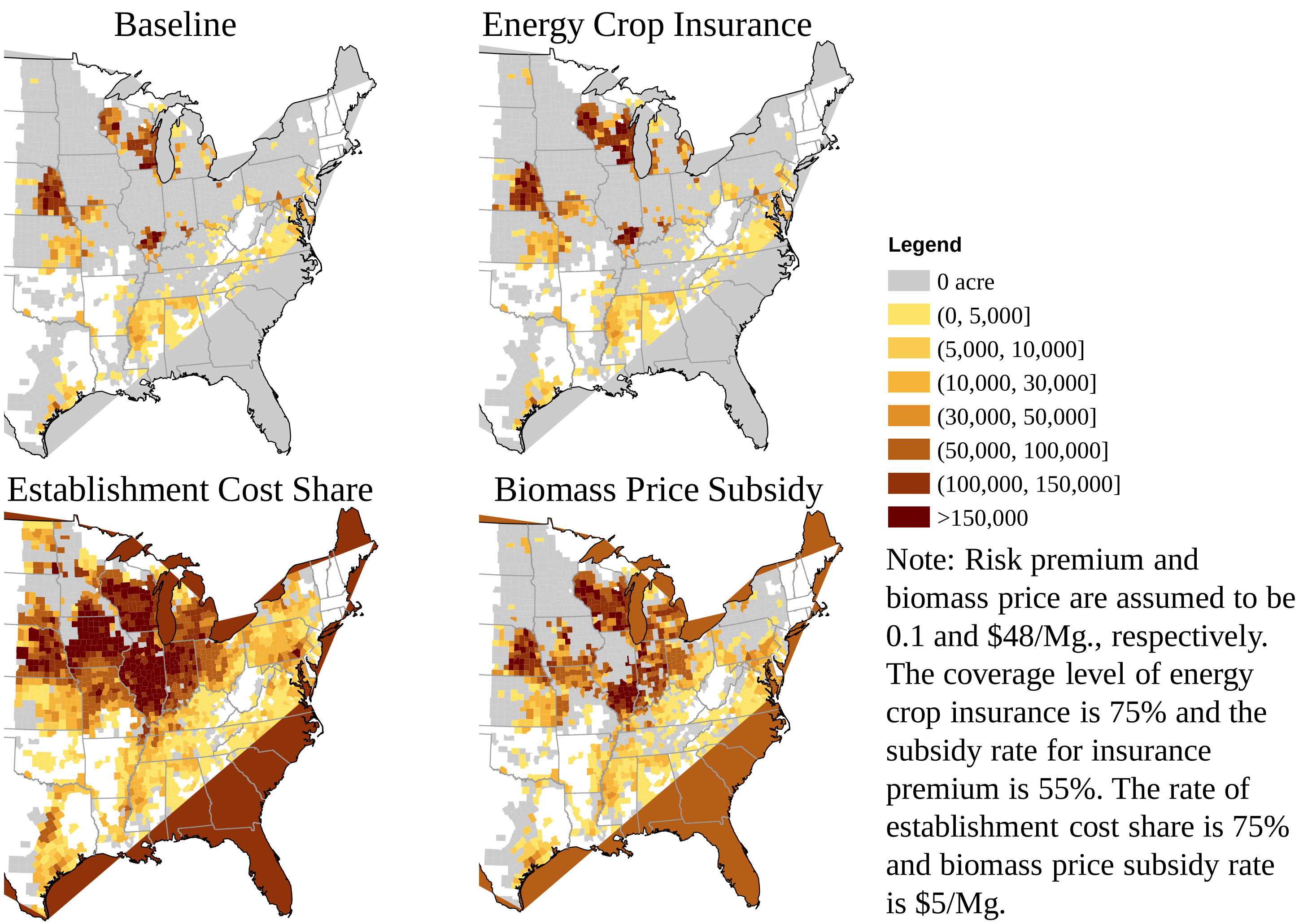
Note: Risk premium and biomass price are assumed to be 0.1 and $48/Mg., respectively. The coverage level of energy crop insurance is 75% and the subsidy rate for insurance premium is 55%. The rate of establishment cost share is 75% and biomass price subsidy rate is $5/Mg.

Figure 1. County Level Acres Devoted to Miscanthus under Low Biomass Price and Credit Constraint



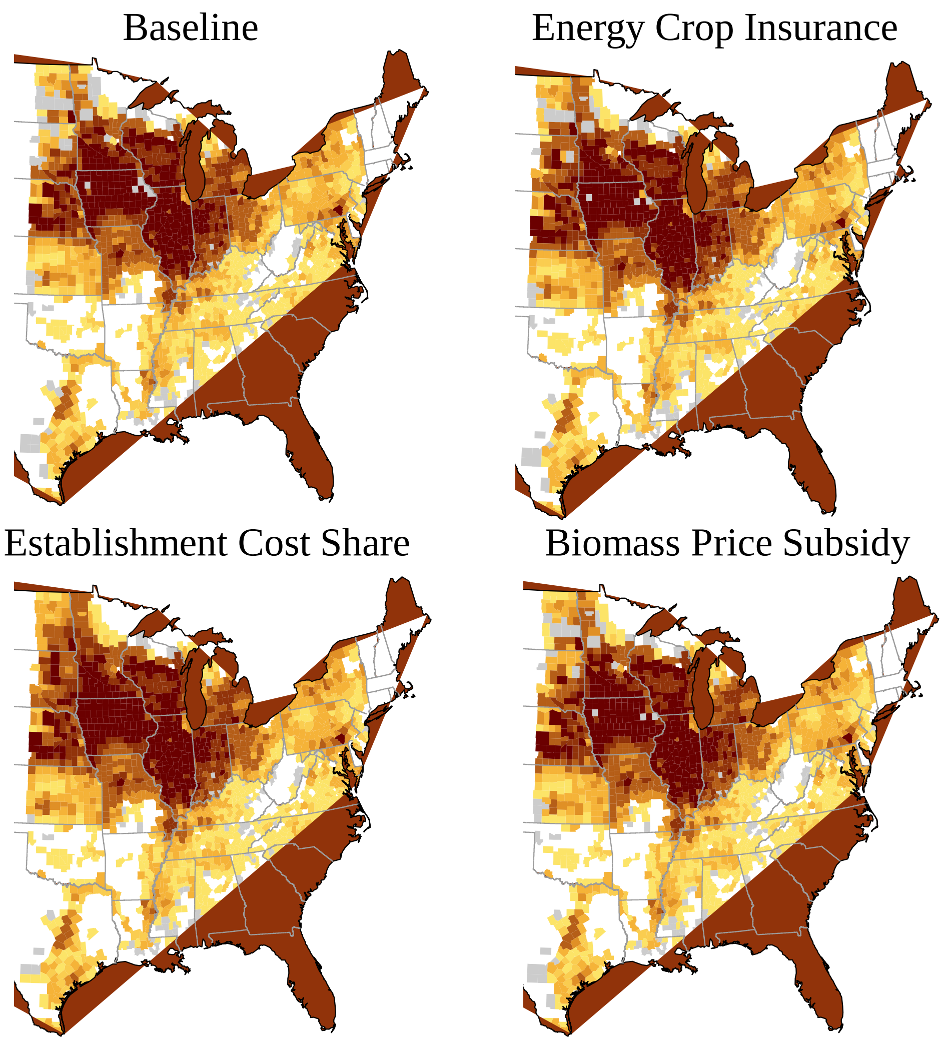
Note: Risk premium and biomass price are assumed to be 0.1 and $81/Mg., respectively. The coverage level of energy crop insurance is 75% and the subsidy rate for insurance premium is 55%. The rate of establishment cost share is 75% and biomass price subsidy rate is $5/Mg.

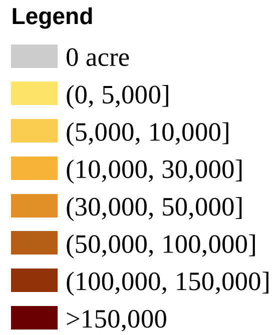
Figure 2. County Level Acres Devoted to Miscanthus under High Biomass Price and Credit Constraint



Note: Risk premium and biomass price are assumed to be 0.1 and $48/Mg., respectively. The coverage level of energy crop insurance is 75% and the subsidy rate for insurance premium is 55%. The rate of establishment cost share is 75% and biomass price subsidy rate is $5/Mg.

Figure 3. County Level Acres Devoted to Miscanthus under Low Biomass Price and No Credit Constraint





Note: Risk premium and biomass price are assumed to be 0.1 and $81/Mg., respectively. The coverage level of energy crop insurance is 75% and the subsidy rate for insurance premium is 55%. The rate of establishment cost share is 75% and biomass price subsidy rate is $5/Mg.

Figure 4. County Level Acres Devoted to Miscanthus under High Biomass Price and No Credit Constraint

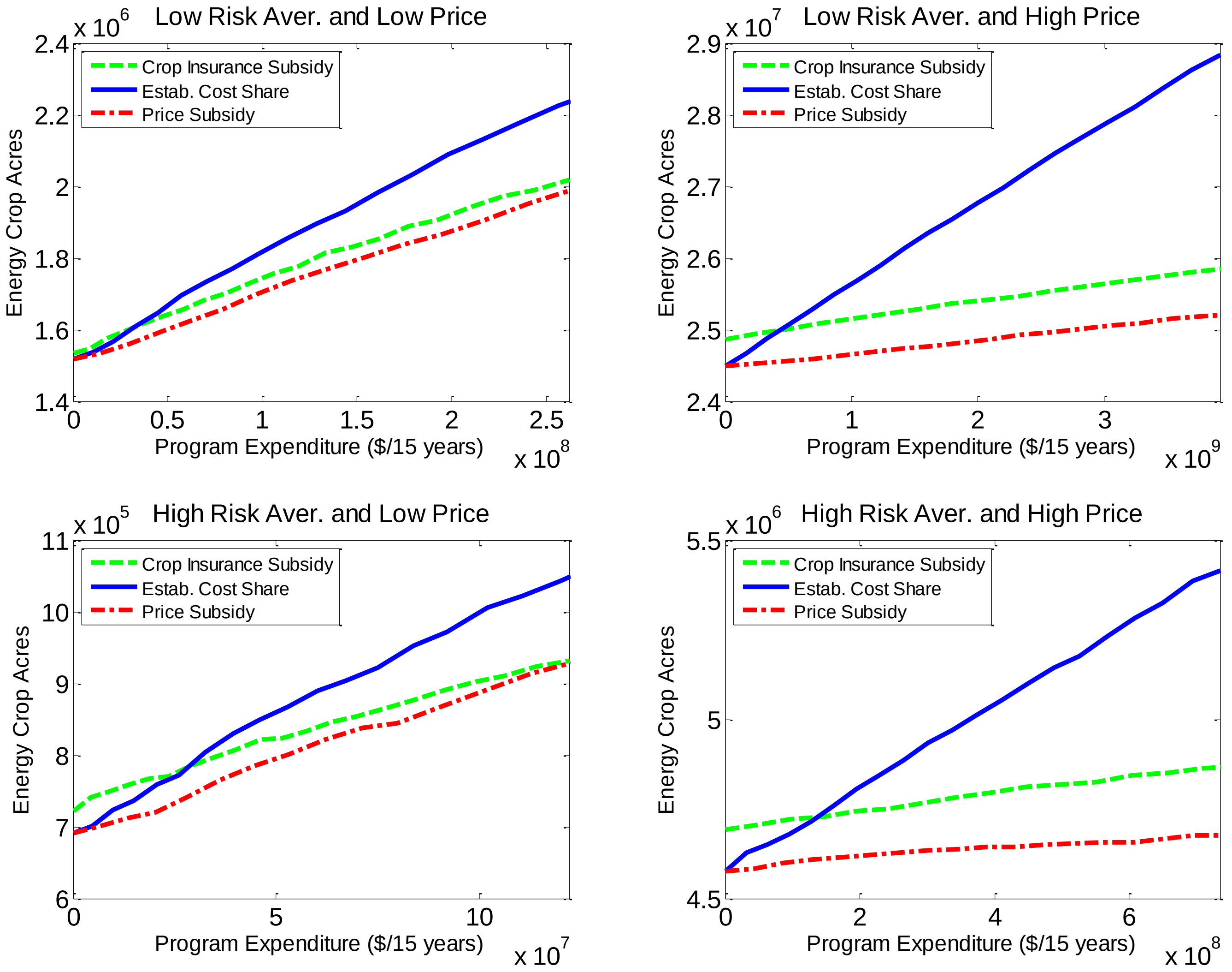


Figure 5. Acreage-Expenditure Relationship under Various Policy Instruments and Scenarios (with credit constraint)

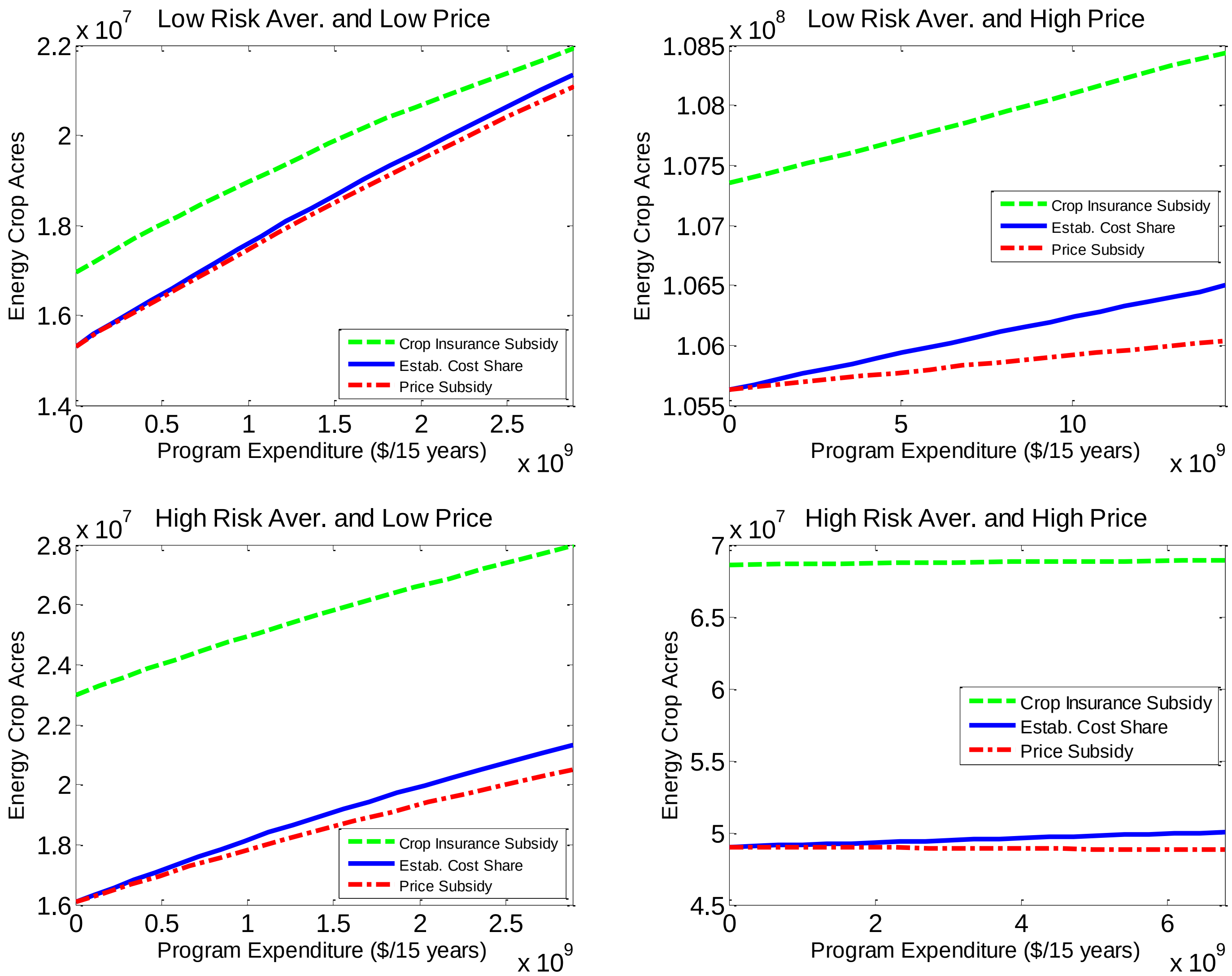


Figure 6. Acreage-Expenditure Relationship under Various Policy Instruments and Scenarios (without credit constraint)

Supplemental Materials for “Crop Insurance for Energy Grass”

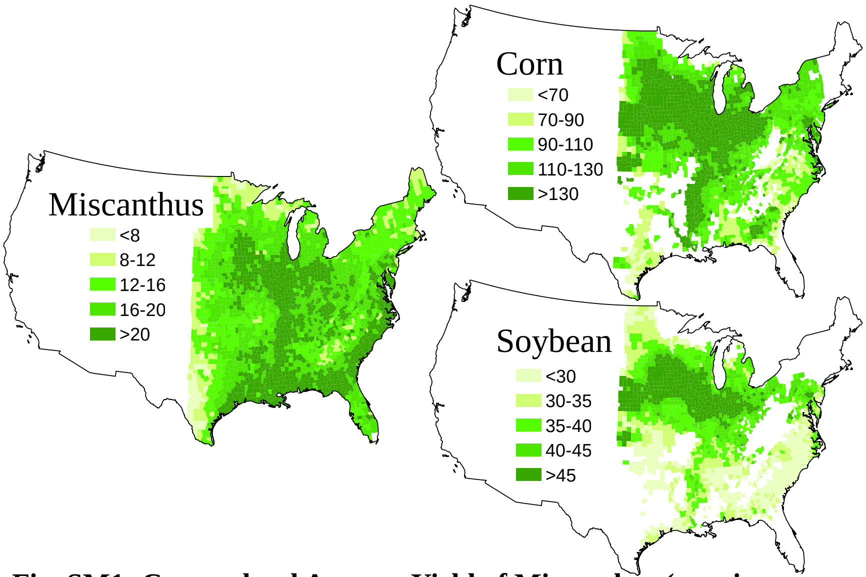


Fig. SM1: County-level Average Yield of Miscanthus (metric tonne/ha.) and Corn and Soybeans (bu./acre)

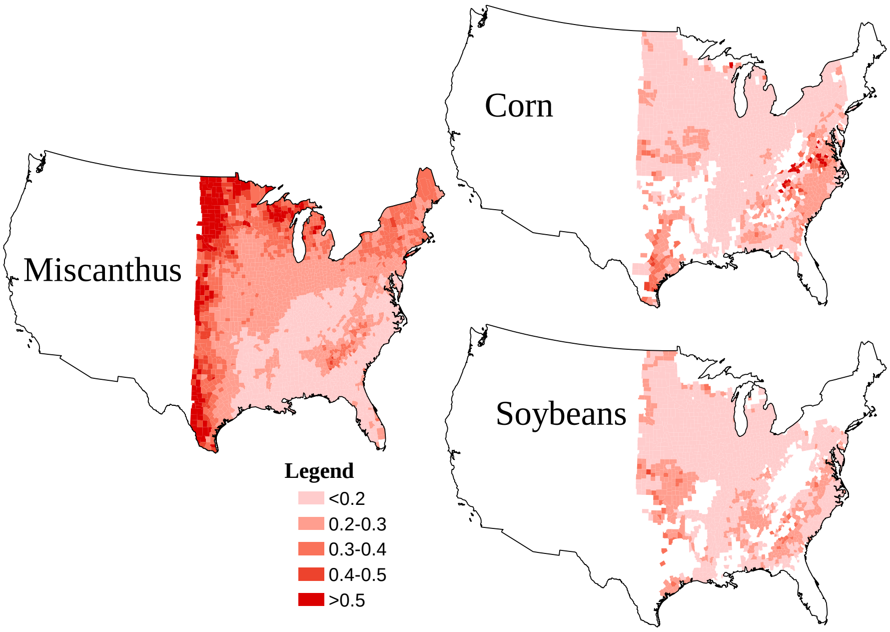


Fig. SM2: Coefficient of Variation of Crop Yields (1979-2010)