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Analysis of Contracting Alternatives for Switchgrass as a Production Alternative on an East Tennessee Beef and Crop Farm

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The Energy Independence and Security Act of 2007 has prompted the development of renewable energy. The research objective was to determine what contracting terms provide sufficient incentives for farmers to establish switchgrass on high- and low-quality cropland compared to traditional enterprises on a representative East Tennessee farm. Contracting alternatives, including a spot market, University of Tennessee Biofuels Initiative, and an expected yield contract, were analyzed. It was determined that contracting incentives analyzed would not be sufficient to encourage switchgrass production on any cropland on the representative farm.

Key words: contract, net returns, risk aversion, stochastic dominance, switchgrass.

Introduction

The development of renewable energy sources from agricultural feedstocks is being spurred by the Energy Independence and Security Act of 2007 (EISA; US House of Representatives, 2007) and the Food, Conservation, and Energy Act of 2008 (FCEA; US House of Representatives, 2008). EISA mandates that US retailers sell 36 billion gallons per year of biofuels by the year 2022 (if they are produced), with 21 billion gallons per year expected to be forthcoming from lignocellulosic feedstocks such as urban waste, forest biomass, and biomass from dedicated energy crops (US House of Representatives, 2007). With this aggressive goal, lignocellulosic materials from crops such as switchgrass will be needed to meet the mandate. Thus, information about the farm-level costs, returns, and variability of net returns (risk) from producing lignocellulosic crops such as switchgrass are needed to inform decision makers as they plan how to meet the mandate. Switchgrass may be a feasible alternative, but questions remain as to its competitiveness with the other enterprise alternatives farmers have available (James, Swinton, & Thelen, 2010). Switchgrass must be competitive with other crop and livestock activities in terms of expected net returns and risk.

Switchgrass is a perennial crop with a lifespan of 10 or more years. Typically, it takes up to three years for switchgrass to reach its full yield potential after establishment (Walsh, 2007). Mooney, Roberts, English, Tyler, and Larson (2009) reported first- and second-year switchgrass yields that average 14% and 60%, respectively, of third-year yields for several landscapes and soil types within an experiment in Milan, Tennessee. Some experts recommend not harvesting the crop in the first year to allow more root establishment to take place (McLaughlin et al., 1998; Walsh, 2007). The establishment of a switchgrass stand is often difficult because of seed dormancy, soil moisture and temperature conditions with spring planting, and weed competition during the establishment phase (Rinehart, 2006). Thus, farmers may be reluctant to grow switchgrass as a dedicated energy crop because of the upfront costs to establish the stand and the delay in the uncertain revenue stream from selling biomass to a bio-refinery (Larson, 2008). In addition, switchgrass is bulky and less dense than corn grain and woody feedstock materials which could make switchgrass more difficult and expensive to harvest, store, and transport than other crops (Cundiff & Marsh, 1996).

Contracts with price and other production incentives may provide a means of encouraging production of perennial energy crops such as switchgrass (Larson, English, & He, 2008). Currently, there is little information about the costs, returns, and riskiness of cellulosic biomass production under different contract incentives. The conditions under which switchgrass may be competitive (in regards to contract terms, planting incentives, and/or cost share incentives) are studied here for a representative beef cattle and crop farm in East Tennessee. The objective of this article is to determine what contracting terms provide sufficient incentives for Tennessee farmers to grow switchgrass on cropland and to evaluate the switchgrass contract incentives that could be offered by a biorefinery to encourage a farmer to produce switchgrass under risk.

Methods and Data

Study Area

The study area is located in East Tennessee and is centered on the city of Vonore. Farmers in this area have traditionally produced corn, soybeans, wheat-soybeans double-cropped, hay, pasture, and beef cow-calves (US Department of Agriculture [USDA], National Agricultural Statistics Service [NASS], 2008), but energy-crop production might become a feasible enterprise in the region due to the opening in January 2010 of the pilot cellulosic biorefinery in Vonore (Willet, 2010). The feedstock contracting region was determined by a 50-mile radius centered on the biorefinery in Vonore, Tennessee. A successful pilot plant could result in the development of a commercial-size biorefinery. Thus, a large and stable supply of feedstock may be required for the plant.

Because switchgrass can be high yielding on marginal land (Fuentes &Taliaferro, 2002), it could potentially be used as the primary feedstock for the biorefinery as well as being introduced into the feasible crop mix in the study region. Typical soil types to be used for the representative farm are Dunmore, Dewey, and Dandridge (USDA Natural Resource Conservation Service [NRCS], 2008). In general, Dunmore and Dewey soils are deep, well-drained soils typically found in valleys and are well suited to row cropping. Dandridge soil is shallow and excessively drained and is frequently found on upland slopes; thus, it is not conducive to row cropping. Dunmore, Dewey, and Dandridge soils represent 18%, 27%, and 55% of the representative farm, respectively. The aforementioned soil types are not an exhaustive list of soils in the study region but are three soils typically cropped in the East Tennessee River Basin (USDA NRCS, 2008).

Net Returns

Farmers are assumed to be price takers for production inputs purchased and outputs sold. The producer's objective is to choose the mix of crop and livestock enterprises that maximizes utility of profit. Switchgrass is grown as a feedstock for energy production and has limited other uses. From a farmer's perspective, the potential annual profit from producing switchgrass as a feedstock for energy production is:

$$SGNR_{s,l,w} = Revenue_{s,l,w} - Cost_{s,l,w} = SGR(Y_{s,w})_l - SGC(Y_{s,w})_l, \quad (1)$$

where s is soil type, l is switchgrass production contract type offered by the biomass processor, w is year, $SGNR$ is net return from switchgrass production ($/acre), SGR is switchgrass returns ($/acre), SGC is switchgrass production costs ($/acre), and SGY is switchgrass yield (dry tons/acre). Both return and cost depend on switchgrass yield (dry tons/acre), which varies by soil type. Depending on risk preference, the producer would want to maximize the utility of profit either by maximizing expected value if risk neutral or trading off between expected value and risk (i.e., variability of profit) if risk averse when deciding whether to include switchgrass in the mix of farm enterprises.

Revenues from switchgrass production may come from several sources and can be modeled using:

$$\begin{aligned} SNR_{s,l,w} = {} & \mathrm{PETH}_{l,w} \times \mathrm{ETHY}_{l,w} \times \mathrm{SGY}_{s,w} \\ & + PCOP_{l,m,w} \times COPY_{l,m,w} \times SGY_{s,w} \\ & + PCARB_{l,w} \times CARB_{l,w}, \end{aligned} \quad (2)$$

where $PETH$ is the price for ethanol ($/gal) produced from the switchgrass adjusted for the cost of conversion by reducing the conversion efficiency, $ETHY$ is the yield of ethanol (gallons) from a ton (dry matter basis) of switchgrass, $PCOP$ is the price of co-product m ($/unit), $COPY$ is the yield of co-product m from a ton of switchgrass (units), $PCARB$ is the price of soil carbon stored ($/ton), $CARB$ is the soil carbon stored by producing switchgrass (dry tons/acre), and all other terms are as previously defined.

Because switchgrass is a perennial crop, it is only planted once in a lifespan of ten years or more (Walsh, 2007). Thus, production costs include the establishment costs incurred in the first year of production and the recurring annual costs for nutrients, pest control, harvest, and storage, and can be modeled using Equation 3.

$$\begin{aligned} \mathrm{SGC}_{s,l,w} = {} & \mathrm{EST(DFP)}_{l,w} + \mathrm{NIT}(\mathrm{DFP}_w, \mathrm{NFP}_w)_l \\ & + \mathrm{MOW}(\mathrm{DFP}_w)_l + \mathrm{RAKE}(\mathrm{DFP}_w)_l \\ & + \mathrm{BALE}(\mathrm{DFP}, \mathrm{SGY}_{s,w})_l \\ & + \mathrm{STAGE}(\mathrm{DFP}, \mathrm{SGY}_{s,w})_l + \mathrm{STORE}(\mathrm{SGY}_{s,w})_l \\ & + \mathrm{OTHER}, \end{aligned} \quad (3)$$

where EST is switchgrass establishment expenses amortized either over the life of a contract to produce switchgrass or over the expected life of the stand ($/acre); NIT is nitrogen fertilization costs; MOW, $RAKE$, $BALE$, $STAGE$, and $STORE$ are the labor, operating, and ownership costs of mowing, raking, baling, handling, and storing switchgrass ($/ton); $OTHER$ includes the other costs

Table 1. Crop, hay, and switchgrass yield simulation statistics.

Soil type		Units	Mean	Standard deviation	Minimum	Maximum
Dunmore	**Corn**	bu	160.7	8.9	134.8	181.0
	Soybeans	bu	50.3	3.3	42.5	57.1
	Wheat	bu	52.0	7.6	35.1	72.9
	Hay	ton	2.2	0.3	1.4	3.2
	Switchgrass	dry ton	4.9	1.7	1.2	8.3
Dewey	**Corn**	bu	160.2	9.2	131.8	181.3
	Soybeans	bu	50.2	3.6	36.3	57.1
	Wheat	bu	53.2	9.9	34.1	74.2
	Hay	ton	2.2	0.3	1.3	3.1
	Switchgrass	dry ton	7.0	2.5	2.2	12.5
Dandridge	**Corn**	bu	45.7	11.2	21.8	80.8
	Soybeans	bu	17.6	4.5	8.0	31.1
	Wheat	bu	46.6	8.8	28.6	65.3
	Hay	ton	1.5	0.2	0.9	2.1
	Switchgrass	dry ton	6.8	2.4	1.9	12.2

of production that do not vary with *s*, *l*, or *w*, including amortized establishment costs (University of Tennessee [UT], Institute of Agriculture, 2008); and all other terms are as previously defined. The variables assumed to be random in Equations 1, 2, and 3 are diesel fuel price (*DFP*, $/gal), nitrogen fertilizer price (*NFP*, $/lb), and switchgrass yield (*SGY*, ton/acre). After establishment, diesel fuel and nitrogen fertilizer are the two most costly inputs purchased in each year of production. Besides impacting revenues, higher yields increase field time per acre to harvest and handle switchgrass, thus increasing fuel, labor, and other operating and ownership costs.

Simulation Methods

The crop simulation model Agricultural Land Management Alternatives with Numerical Assessment Criteria (ALMANAC) was used to generate crop, hay, pasture, and switchgrass yields for each production alternative and soil type on the representative farm for 100 years (Kiniry et al., 2005). The ALMANAC model is a daily-time-step, process-based general crop model that uses daily weather data to simulate crop yield distribution under different fertility, crop rotation, and tillage regimes. The ALMANAC model was chosen for this study because it is capable of simulating many crops, including perennials such as switchgrass (Kiniry, Williams, Gassman, & Debaeke, 1992). The model was adapted to the soil types in the study area using switchgrass establishment and mature yields from a field experiment reported by Mooney et al. (2009) and the knowledge and expertise of a soil scientist (D.D. Tyler, personal communication, November 2009) and a crop simulation modeler (V. Benson, personal communication, July 2010). Table 1 presents the descriptive statistics from the crop, hay, and switchgrass simulation.

The @Risk simulation model in Decision Tools Suite (Palisade Corporation, 2007) was used to simulate a random set of detrended, correlated prices for corn, soybeans, wheat, hay, switchgrass, lignin, fertilizer, and diesel fuel for 100 years (Palisade Corporation, 2007). Historical prices were inflated to 2007 dollars using the Implicit Domestic Product Price Deflator (US Congress, 2008) and placed in a cumulative distribution and the simulation model @Risk in Decision Tools Suite (Palisade Corporation, 2007), which uses Monte Carlo simulation, simulated 100 years of correlated prices. Though historical prices are generally a good indicator of the market, there has been a transformation in agricultural commodity prices to a higher level. Therefore, average monthly futures prices from the Chicago Mercantile Exchange for a September contract were collected for corn and soybeans, and prices for a July contract were collected for wheat in order to simulate the price transformation (Chicago Mercantile Exchange, 2012). Futures prices were simulated using a triangular distribution. Table 2 contains a summary of price simulation statistics and distributions used in the simulation.

There were no readily available historical prices for switchgrass so the simulation of switchgrass prices was approached from the direction of developing an energy-equivalent price series for switchgrass as an ethanol-based energy substitute for gasoline. Ethanol prices have moved on an energy equivalent basis with gasoline

Table 2. Price simulation statistics and distributions used in the simulation.

		Units	Mean	Standard deviation	Distribution
Historical prices	**Corn**	$/bu	2.74	0.30	Cumulative
	Soybeans	$/bu	4.27	1.77	Cumulative
	Wheat	$/bu	3.92	0.44	Cumulative
	Hay	$/ton	35.00	11.07	Cumulative
	Switchgrass	$/ton	29.85	6.41	Cumulative
	Nitrogen	$/lb	0.41	0.06	Cumulative
	Diesel fuel	$/gal	1.91	0.57	Cumulative
	Heifers (465 lbs)	$/cwt	102.77	23.40	Cumulative
	Steers (510 lbs)	$/cwt	111.45	23.63	Cumulative
	Cull cows (1,000 lbs)	$/cwt	66.62	20.52	Cumulative
Futures prices	**Corn**	$/bu	5.45	0.89	Triangular
	Soybeans	$/bu	11.68	1.55	Triangular
	Wheat	$/bu	7.39	0.94	Triangular
	Heifers (450-500 lbs)	$/cwt	169.06		
	Steers (500-550 lbs)	$/cwt	171.75		
	Cull cows (1,000-1,100 lbs)	$/cwt	76.81		

since 2002 (Tyner, 2009). The assumed sources of revenue for switchgrass included ethanol, carbon credits from the Chicago Climate Exchange, and electricity from burning lignin, which is a component of switchgrass that cannot be converted into ethanol. Switchgrass and lignin prices were simulated under a cumulative distribution, while the carbon credit prices were simulated under a triangular distribution. Table 2 contains a summary of price simulation statistics and distributions used in the simulation.

A 100-year distribution of net returns for each crop activity was simulated. The variables treated as random in the simulation of net returns were crop prices, crop yields, nitrogen fertilizer price, diesel fuel price, and switchgrass harvest and transportation costs as a function of harvested yield and diesel fuel price. Simulated switchgrass yields and amortized establishment costs were based on reestablishment of the stand after the end of a five-year contract and a ten-year contract. Though a stand of switchgrass has a longer life than five years, reestablishment every five years was assumed due to the expectation of the development of higher yielding varieties and the need for producers to recoup their investment within the contract period. Switchgrass production with reestablishment every ten years was also analyzed to perform sensitivity on reestablishment length. Cellulosic production contracts will likely be of a shorter length than other energy contracts and in the range of 5 to 7 years because of constraints on capital availability for lignocellulosic biorefinery startups (Forest2Market, 2009).

The assumption is that the representative farm would want to recapture establishment costs by the end of the contract because of a lack of alternative uses and would base expectations about yields, costs, and net returns on a five-year stand life. A ten-year stand life was also constructed to address the sensitivity of returns to establishment costs. Net returns for 99 years were used in the analysis because of the double crop alternative not being fully represented in Year 1, thus crop years 2 through 100 represented the 99 years of net returns. Prices for the beef cow industry were simulated using the @Risk simulation model in Decision Tools Suite (Palisade Corporation, 2007).

Price and Budgeting Data

The price data used in constructing the cumulative distribution functions (CDF) for corn, soybeans, wheat, and hay was compiled from USDA NASS for the State of Tennessee for the years 1977 through 2007 (USDA NASS, 2008). Switchgrass price data was not readily available, so an energy-equivalent price series for switchgrass as an ethanol-based energy substitute for gasoline was constructed using historical wholesale gasoline price data that was put into real terms by inflating the historical prices to 2007 dollars using the Implicit Domestic Product Price Deflator (US Congress, 2008). The net energy values from ethanol (the amount of energy in a gallon of ethanol minus the energy required to convert switchgrass to ethanol in the biorefinery) were estimated to be 2.567 million BTUs per dry ton for switchgrass based on assumptions from Wang, Saricks, and Santini (1999). The net energy BTUs per dry ton of switchgrass was multiplied by the average Tennessee wholesale gasoline price per million BTUs for 1977 to 2005 (US Department of Energy [DOE], 2007) to create a price series for switchgrass. Gas prices were inflated to 2007 dollars using the Implicit Domestic Product Price Deflator before creating the switchgrass price series (US Congress, 2008).

An energy-equivalent price series was also constructed for burning lignin to generate electricity. Lignin energy content was estimated to be a little more than 3.005 million gross BTUs and 2.404 million net BTUs (the amount of energy in a ton of lignin minus the energy required to convert lignin to electricity in the biorefinery) from a ton of switchgrass based on assumptions by De La Torre Ugarte, English, Hellwinckel, Menard, and Walsh (2007). The net energy BTUs per dry ton of switchgrass were then multiplied by the average Tennessee coal price per million BTUs from 1977 to 2005 (US DOE, 2007) to create a price series for lignin. Coal prices were inflated to 2007 dollars using the Implicit Domestic Product Price Deflator before creating the lignin price series (US Congress, 2008).

Daily settlement prices for carbon—as a potential revenue source for switchgrass—were collected from the Chicago Climate Exchange (Chicago Climate Exchange, 2008) from April 2006 to October 2008 for a December 2009 carbon contract. Monthly prices for carbon were calculated by averaging the daily settlement prices. The monthly average price for December was used in the simulation of carbon prices. The collected price data were placed in a triangular distribution, which requires a minimum, maximum, and mean value and was then used in the simulation of prices using @Risk (Palisade Corporatation, 2007), while the yield data were used in the simulation of yields using ALMANAC (Kiniry et al., 2005).

The cattle enterprise was modeled using the University of Tennessee's enterprise budget for a cow-calf enterprise (Rhea, Rawls, McKinley, Ferguson, 2007). Historical prices for 510-pound steers, 465-pound heifers, and 1,000-pound cull/utility cows were obtained from USDA NASS for Tennessee for the years 1977 through 2007 (USDA NASS, 2008) for the purpose of simulating cattle prices. The historical prices were inflated to 2007 dollars using the Implicit Domestic Product Price Deflator (US Congress, 2008) and then put into a cumulative distribution function. In order to address the transformation to higher price levels that have occurred in the cattle industry, weighted average prices for heifers, steers, and cull/utility cows were obtained from the East Tennessee Livestock Center (USDA Tennessee Department of Agriculture, 2012) and used to simulate a price series with higher prices using a triangular distribution. The simulated prices were then used to generate 99 years of net returns.

Stated Contract Provisions/Strategies Evaluation

There are a countless number of contract terms and provisions that could be written for switchgrass production purposes. Recognizing that it would be near impossible to construct and analyze all potential possibilities, current contract terms and provisions were analyzed as well as some possible variations to the existing contracts that might increase net returns.

The current contract being offered by the University of Tennessee Biofuels Initiative compensates the contractor with an annual $450/acre payment (UT Contract, 2009). The payment is the same for all land types regardless of the land's production potential. The payment and contract terms were constructed in a manner to induce switchgrass production in east Tennessee. Acreage payments guard the producer against price and yield risk. Cost of production risk is reduced because fuel cost can be adjusted annually based on positive changes in the US Gulf Coast No.2 Diesel Low Sulfur average price in the first week of October for the year the crop is harvested compared to that same price in 2007, which was $2.24/gallon. The stated contract has a first-year adjustment as a result of planting, weed control, and harvesting activities based on 40.65 gallons/acre of diesel, while Years 2 and 3 would be adjusted based on 32.4 gallons/acre of diesel fuel. The current contract has the energy company being responsible for loading and hauling the switchgrass from the contractor's property to the biorefinery, but the producer is responsible for harvest and storage. The contract also provides that UT supplies the seed for all acres contracted to help offset establishment costs (UT Contract, 2009), which also reduces production-cost risk to the producer.

A contract with a set price per ton that is based on expected yield over the life of the contract is another way in which switchgrass could be marketed through a contractual agreement (Larson et al., 2008). The expected revenue contract is similar to the UT Biofuels Initiative in that it reduces price and yield risk to the producer, but in contrast, it does not guard against production-cost risk.

Table 3. Net return statistics for FSD and selected alternatives for all soils using historic prices.

			Net revenue ($/acre)			
Soil type	**Alternative [a]**	**Risk efficiency criteria [b]**	**Mean**	**Standard deviation**	**Maximum**	**Minimum**
Dunmore	**Corn [c]**	FSD and SSD	130	58.1	290	-13
	Soybeans		38	90.3	286	-117
	UTNo		26	102.4	177	-211
	UTCCX		36	102.3	185	-203
	UTNoTen		50	102.5	199	-188
	UTCCXTen		56	102.4	208	-181
Dewey	**Corn [c]**	FSD and SSD	128	58.2	290	-12
	Soybeans		38	90.5	286	-117
	UTNo		5	100.8	154	-229
	UTCCX		11	100.7	163	-225
	UTNoTen		28	100.9	177	-206
	UTCCXTen		35	100.8	186	-202
Dandridge	**Beef [c]**	FSD	11	63.2	220	-169
	UTNo	FSD and SSD	26	61.8	154	-138
	UTCCX	FSD and SSD	32	61.6	157	-131
	UTNoTen	FSD and SSD	50	61.7	176	-116
	UTCCXTen	FSD and SSD	56	61.4	179	-108

[a] This column identifies the dominate traditional enterprise and the FSD and selected switchgrass contract alternatives and revenue sources (UT = University of Tennessee Biofuels Initiative Contract; No = ethanol is sole revenue source; CCX = Chicago Climate Exchange carbon credits; Ten = assumes reestablishing switchgrass every ten years, all other contracts assume reestablishing switchgrass every five years). All switchgrass alternatives include ethanol as a source of revenue.
[b] Compares switchgrass contract alternative with traditional enterprise individually. FSD = first-degree stochastic dominance set; SSD = second-degree stochastic dominance set
[c] FSD and SSD of traditional enterprises.

A spot market price is another option. The spot market price would be based on ethanol's energy-equivalent price to gasoline. The farmer assumes all of the price, yield, and production-cost risk with the spot market option.

The base situations and contracts, as described previously, are the UT Biofuels Initiative, expected yield price, and spot market. As presented above, the only revenue source being evaluated is revenue from ethanol. Switchgrass has the potential for other revenue sources, such as co-products and carbon credits. During conversion, electricity is a co-product generated from burning lignin. Carbon credits are a potential revenue source in that switchgrass has the ability to sequester carbon (Burras & McLaughlin, 2002) and futures trading of carbon dioxide takes place on the Chicago Climate Exchange. Switchgrass has been found to store 1.79 tons of carbon dioxide per acre (McLaughlin & Walsh, 1998) and 1.5 tons of carbon dioxide per acre (Burras & McLaughlin, 2002). Ethanol production in conjunction with a co-product and/or carbon credits would affect switchgrass revenues and thus the ability of switchgrass to compete with alternative enterprise options in the study region.

Stochastic Dominance and Risk-Efficient Systems

The generalized stochastic dominance computer program developed by Goh, Shih, Cochran, and Raskin (1989) was used to identify the first-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) set of the traditional enterprises on the soil types analyzed for both the historical price series and the futures price series. The FSD and SSD of the traditional enterprises were reanalyzed in the Goh et al. (1989) program to determine the FSD and SSD set from the top traditional enterprises and switchgrass contract alternatives, including the spot market and UT Biofuels Initiative. Spot-market switchgrass had four alternatives based on revenue sources, with the base case revenue source being limited to ethanol while other alternatives included electricity (Elec), carbon credits from the Chicago Climate Exchange (CCX), and Elec and CCX in addition to ethanol. UT Biofuels Initiative had a base

Table 4. Net return statistics for FSD and selected alternatives for all soils using futures price. [a]

Soil type	Alternative [b]	Risk efficiency criteria [c]	Net revenue ($/acre) Mean	Standard deviation	Maximum	Minimum
Dunmore	**Corn**	FSD and SSD	589	110.0	872	334
	Soybeans		414	65.5	585	298
	UTNo		26	102.4	177	-211
	UTCCX		33	102.3	185	-203
	UTNoTen		50	102.5	199	-188
	UTCCXTen		56	102.4	208	-181
Dewey	**Corn**	FSD and SSD	586	109.5	854	337
	Soybeans		412	67.6	583	287
	UTNo		5	100.8	154	-229
	UTCCX		11	100.7	163	-225
	UTNoTen		28	100.9	177	-206
	UTCCXTen		35	100.8	186	-202
Dandridge	**Beef**	FSD and SSD	150	8.1	167	131
	UTNo	FSD	26	61.8	154	-138
	UTCCX	FSD	32	61.7	157	-131
	UTNoTen	FSD	50	61.7	176	-116
	UTCCXTen	FSD	56	61.4	179	-108

[a] Using average monthly Chicago Mercantile Exchange futures prices for a September contract for corn and soybeans and the current average east Tennessee 500-600 pound steer price for beef.
[b] This column identifies the dominate traditional enterprise and the FSD and selected switchgrass contract alternatives and revenue sources (September UT = University of Tennessee Biofuels Initiative Contract; No = ethanol is sole revenue source; CCX = Chicago Climate Exchange carbon credits; Ten = assumes reestablishing switchgrass every ten years, all other contracts assume reestablishing switchgrass every five years). All switchgrass alternatives include ethanol as a source of revenue.
[c] Compares switchgrass contract alternative with traditional enterprise individually. FSD = first-degree stochastic dominance set; SSD = second-degree stochastic dominance set

revenue from ethanol as well as CCX in addition to ethanol. Five- and ten-year switchgrass reestablishment contracts were analyzed for the aforementioned contracts.

The FSD and SSD alternatives for the traditional enterprises, the switchgrass contract alternatives, and the base UT Biofuels Initiative were then ordered for different levels of absolute risk aversion, $r(x)$, using the Riskroot computer program (McCarl, 1988). This program identifies breakeven $r(x)$ values where dominance changes between CDF pairs under the assumption of constant absolute risk aversion. This breakeven risk-aversion coefficient (BRAC) is the point where the expected utility difference between the two points is zero and identifies the point in which one alternative dominates on one side of the BRAC and the other alternative dominates on the opposite side of the BRAC (McCarl, 1988). McCarl's (1988) Riskroot program was then used to determine the expected revenue contract, a set price per dry ton of biomass based on an expected average yield, with no incentives that would dominate the top ranked traditional enterprise at each $r(x)$.

Results and Discussion

Risk-Efficient Traditional Enterprises Using Historic Prices

Net-return statistics for alternatives in the FSD and SSD efficient sets when analyzing historical prices are in Table 3. The FSD risk efficient sets for traditional enterprises were corn ($130/acre mean) for Dunmore soil, corn ($128/acre mean) for Dewey soil, and cow-calf production ($11/acre mean) for Dandridge soil. The same production alternatives for each soil type were also dominant over the other traditional enterprises under the SSD risk efficiency criterion. It is likely that corn was the risk efficient set for Dunmore and Dewey soils because of the soils being more productive and more conducive to row crops than other soils in the region. It is also conceivable that cow-calf production

Table 5. Breakeven risk-aversion coefficients (BRACs) and ordering of FSD risk-efficient set and selected alternatives.

		Ordering of alternatives above the BRAC [b]					
Soil type	**BRAC [a]**	**1**	**2**	**3**	**4**	**5**	**6**
Dunmore	0.009997	Corn	Soybeans [c]	UTCCXTen	UTNoTen	UTCCX	UTNo
	0.006759	Corn	UTCCXTen	Soybeans	UTNoTen	UTCCX	UTNo
Dewey		Corn	Soybeans	UTECX	BCAPNo	UTNoTen	UTNo
Dandridge	-0.021948	UTCCXTen	UTNoTen	UTCCX	UTNo	Beef	
	-0.025822	UTCCXTen	UTNoTen	UTCCX	Beef	UTNo	
	-0.037182	UTCCXTen	UTNoTen	Beef	UTCCX	UTNo	
	-0.041201	UTCCXTen	Beef	UTNoTen	UTCCX	UTNo	

[a] *Rounded to six decimal places.*
[b] *Refer to Table 3, Footnote a.*
[c] *Boldface denotes the stategies where dominance switches at the BRAC.*

was the risk efficient set for Dandridge soil because it is a less productive soil type.

Table 4 contains net-return summary statistics for alternatives in the FSD and SSD efficient sets when futures prices are used to calculate net returns. Corn was the FSD and SSD risk efficient set when analyzing traditional enterprise for Dunmore and Dewey soils. Cow-calf production was in the FSD and SSD for the Dandridge soil type.

Risk-Efficient Enterprises Including Switchgrass

When using historical prices, the FSD efficient set when comparing traditional enterprises, switchgrass spot-market contracting alternatives, and UT Biofuels Initiative switchgrass alternatives was corn for Dunmore and Dewey soils. The UT Biofuels Initiative contracts—UTNo ($26/acre), UTCCX ($32/acre), UTNoTen ($50/acre, UT base contract with a 10-year switchgrass reestablishment), and UTCCXTen ($56/acre)—were all in the FSD with beef for Dandridge soil when compared individually with cow-calf production (Table 3). Using the SSD risk efficiency criterion for the same production alternatives, corn dominated the alternatives for Dunmore and Dewey soils. When compared individually with cow-calf production on Dandridge soil, the UT Biofuels Initiative contracts were the SSD risk efficient set. The UT Biofuels Initiative contracts likely entered the efficient set for Dandridge soil because of the higher expected value and the reduction in risk switchgrass production provides relative to beef production. The results indicate that additional revenue sources are needed to induce switchgrass production on Dunmore and Dewey soils. Conversely, the UT Biofuels Initiative contract alternatives would be able to induce production by some decision makers on Dandridge soil, which is less productive than Dunmore and Dewey soil.

When using futures prices, corn dominated switchgrass contracting alternatives with both first- and second-degree stochastic dominance for Dunmore and Dewey soils. Cow-calf production and the UT Biofuels Initiative contracts analyzed were in the FSD set for Dandridge soil, while the SSD set was only cow-calf production (Table 4). With the price transformation that has taken place to a higher price level, it would be difficult to induce switchgrass production on any soil type analyzed.

Ordering of Systems

The Riskroot computer program identified two breakeven risk-aversion coefficients (BRACs) among the alternatives in the FSD risk efficient set for Dunmore soil, zero BRACs for Dewey soil, and four BRACs for Dandridge soil (Table 5) when using historical prices. The ordering of alternatives from "most preferred" to "least preferred" for different $r(x)$ values was influenced greatly by the level of absolute risk aversion. Corn was the top ranked alternative for Dunmore and Dewey soils based on absolute risk aversion. Corn was dominant for all $r(x)$ values on the Dunmore soil and Dewey soil. Corn was in the SSD set for Dunmore and Dewey, which implies that it would be preferred by all risk-averse decision makers and some risk-seeking decision makers. The UTCCXTen switchgrass contract was risk efficient for the Dandridge soil based on the level of absolute risk aversion. UTCCXTen was in the SSD set for Dandridge, ranking it first for all risk-averse decision makers.

Results indicate that risk-averse producers would benefit more from growing corn than switchgrass under the UT Biofuels Initiative contract if the soil type is

Table 6. Expected revenue price's dominance at the BRACs.

		Ordering of alternatives [b]		
Soil type	**BRAC [a]**	**1**	**2**	**3**
Dunmore	0.009997	105CCX [c]	No105	Corn
	0.006759	105CCX	No105	Corn
Dewey		90CCX	No90	Corn
Dandridge	-0.021948	No65	CCX60	Beef
	-0.025822	CCX65	No65	Beef
	-0.037182	CCX65	No65	Beef
	-0.041201	No70	CCX65	Beef

[a] *Rounded to six decimal places.*

[b] *The ordering includes the dominant alternative from Table 2 and the alternatives for a price based on expected yield that dominates the original alternative.*

[c] *Refer to Table 1, Footnote a (i.e., 105CCX is Chicago carbon credit and $105/ton of switchgrass and No105 is $105/ton of switchgrass).*

either Dunmore or Dewey (Table 5). These soils are relatively productive for row-crop production in East Tennessee. Risk-averse producers with Dandridge soil may be better off producing switchgrass if offered a UT Biofuels Initiative contract. As producers become more risk-seeking, cow-calf production increases in rank.

Table 6 compares the top-ranked traditional alternative for each soil type with different price levels for switchgrass that are paid annually based on the expected yield over the life of the contract (i.e., the expected revenue contract). The expected revenue contracts were constructed to determine what price per ton of switchgrass would dominate the top-ranked traditional enterprise. The most risk-averse decision maker with Dunmore soil ($r(x)$ = 0.009997) would have to receive a contract price of $105/dry ton to change from corn production to switchgrass production. The most risk-averse decision maker with Dewey soil would have to receive $90/dry ton to change from corn production to switchgrass production. The contract price required to convert from corn to switchgrass generally diminishes with decreasing risk-aversion behavior.

At the lowest risk aversion analyzed ($r(x)$ = -0.021948) for Dandridge soil, a producer would have to receive $65/dry ton (or $60/dry ton and Chicago carbon credits) to change from cow-calf production to one of the previously mentioned switchgrass production alternatives. The most risk-seeking decision maker ($r(x)$ = -0.041201) with Dandridge soil would have to receive $70/dry ton (or $65/dry ton and Chicago carbon credits) to change from cow-calf production to one of the previously mentioned switchgrass production alternatives.

Switchgrass contracting alternatives are not competitive with corn on Dunmore and Dewey soils. It requires a relatively high contract price for switchgrass to overtake corn as the dominant alternative. The feasibility of paying such a price and the incentives offered by a processor is dependent on the return that a processing plant could receive from switchgrass. Corn being represented in the FSD and SSD shows the crop's ability to dominate and be successful as a production alternative on these two soil types and the difficulty switchgrass may face in trying to induce decision makers to switch current production practices to switchgrass production.

Traditional enterprises dominate switchgrass contracting alternatives when using the futures prices. The price transformation to a higher price level that has taken place over the past few years makes it difficult for any of the switchgrass contracting alternatives analyzed in this study to be competitive with traditional enterprises.

Summary and Conclusions

This article evaluated traditional production alternatives as well as a few contracting and production alternatives for switchgrass in the contracting region to determine a ranking of the production alternatives based on risk behaviors. The analysis covered a specific contracting region in East Tennessee and included three typical soil types for the area.

The ranking of alternatives was based on simulated net returns for each of the production alternatives on each soil type and ranked based on first- and second-degree stochastic dominance. Dunmore and Dewey soils tend to be more productive soils than Dandridge soil. More productive soils are more conducive to row-crop production. The results for the more productive soils suggest that producers would benefit most from corn production. Additional revenue sources beyond those studied in addition to risk reduction and subsidies would be necessary to induce switchgrass production on the relatively more productive soils in the East Tennessee contracting region.

Switchgrass becomes more competitive with traditional enterprises on the less productive Dandridge soil, but the risk-preferred contract terms differ based on risk behavior of different producers. Results suggest risk-averse producers would benefit from producing switchgrass with the UT Biofuels Initiative contract. Less productive soils, such as Dandridge, are more suited to cow-calf production and switchgrass production than to row-crop production. Subsidies and risk-deferring contract terms could make switchgrass production on less productive soils a more profitable enterprise than traditional enterprises and entice producers to grow switchgrass.

The UT Biofuels Initiative contract reduces price and yield risk to the producer as well as reducing production-cost risk, which is favorable to switchgrass production. The expected revenue contract guards producers against both price and yield risk, which is advantageous from a producer's standpoint. Spot-market prices for switchgrass that are based on historical energy prices are not advantageous to the production of switchgrass. Switchgrass spot markets provide no risk protection for output price, yield, or input price for producers of the commodity; the results indicate that it would take a price higher than the energy equivalent to induce switchgrass production under a spot-market pricing system. The UT Biofuels Initiative base contract for switchgrass could induce production on the less productive soil (Dandridge) in the region for some decision makers based on risk behavior, but it would take additional revenue sources to induce production by all decision makers based on risk behavior.

Switchgrass appears to be a feasible alternative for producers with marginal lands in the contracting region, but not producers with cropland. Switchgrass production and storage requires haying equipment to harvest, stage, and store, which would force grain-crop producers into additional costs (equipment or custom harvest). Beef producers who harvest their own hay would likely have most of the needed machinery and storage facilities.

Though this study is representative of the study area based on historical data, it still has limitations. The study evaluated expected net returns for production of traditional enterprises commonly produced in the study region, as well as switchgrass. Thus, the study did not evaluate every possible production alternative that could occur in the region. Whole-farm planning would be difficult with this study because the study was based on per-acre net returns for enterprise alternatives and included no constraints. The study simply ordered the enterprise alternatives that produced the highest expected net returns without regard to on-farm constraints.

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