Stochastic Dominance Analysis of Bioenergy Crops as a Production Alternative on an East Tennessee Beef and Crop Farm

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Selected Paper prepared for presentation at the
Southern Agricultural Economics Association Annual Meetings
Atlanta, GA, January 31-February 3, 2009.

Abstract: This study evaluated prices and incentives for switchgrass stated in a biorefinery's contract terms that induce switchgrass production on an east Tennessee representative farm when compared with traditional enterprises. The alternate contract terms imitated current subsidies/incentives offered as well as incentives and cost share terms not in the BCAP.

Keywords: switchgrass, contract, risk aversion, net return.

JEL Classifications: Q12

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Introduction

The development of renewable energy sources from agricultural feedstocks is being spurred by the Energy Independence and Security Act of 2007 (EISA) and the Food, Conservation and Energy Act of 2008 (FCEA) (U.S. Congress, 2007, 2008). EISA mandates that 36 billion gallons per year of ethanol be produced in the U.S. by 2022, with 21 billion gallons per year coming from feedstocks other than corn (U.S. Congress, 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 on 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. 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 et al. (2008) reported first- and second-year switchgrass yields that average 14- and 60-percent of third-year yields for several landscapes and soil types in an experiment at Milan, TN. 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 (Rhinehart, 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 and Marsh, 1996).

Contracts with price and other production incentives may provide a means of encouraging production of perennial energy crops such as switchgrass (Larson et al., 2008). For example the Food, Conservation and Energy Act of 2008 addresses farm level production of annual and perennial energy crops (U.S. Congress, 2008). The Act establishes a Biomass Crop Assistance Program (BCAP) in order to induce farmers to produce biomass crops in regions with biomass-to-energy conversion facilities. The BCAP allows biomass producers to contract with the USDA for up to five years and receive up to 75 percent of establishment costs for the crop. The contract also allows for annual payments up to $45/ton of biomass for harvest, storage, and transport. Cost sharing arrangements similar to the BCAP could be used by a biorefinery to share risk with growers.

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 paper is 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 in East Tennessee includes Blount, Bradley, Knox, Loudon, McMinn, Meigs, Monroe, Polk, Rhea, and Roane counties. Farmers have traditionally produced corn, soybeans, wheat-soybeans double cropped, hay, pasture, and beef cattle (U.S. Department of Agriculture-NASS), but energy crop production is now a feasible enterprise in the region because of the development of the biorefinery in Vonore (The University of Tennessee 2008b). The pilot size biorefinery will have a 250,000 gallon annual capacity and will produce ethanol from cellulosic energy crops corn stover and switchgrass. Because switchgrass can be a high yielding crop on marginal land (Fuentes and Taliaferro 2002) it may be a potential energy crop that can be introduced into the feasible crop mix in the study region at hand.

The representative farm will also have the potential to produce switchgrass. Typical soil types to be used for the representative farm are Dunmore, Dewey, and Dandridge soils. 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 (U.S. Department of Agriculture-NRCS). The feedstock supply or contracting region, which determined the counties represented and studied, was determined by lying within 50 miles of the biorefinery in Vonore, Tennessee (Dr. Clark Garland, personal communication May 21, 2008).

Data

The price data that was used in constructing the cumulative distribution functions for corn, soybeans, wheat, and hay was compiled from the U.S. Department of Agriculture-NASS for the state of Tennessee. Steer, heifer, and cull cow prices for the beef cattle enterprise were also collected from the U.S. Department of Agriculture-NASS. The data was used in the simulation and construction of net returns for each enterprise.

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 the net present value of profit or wealth. Switchgrass is grown as a feedstock for energy production and has limited other uses. The assumed time for a single harvest of switchgrass is in the fall after a killing freeze. Conventional hay equipment is used to harvest, stage, and store switchgrass on the farm before it is transported to the processing plant. From a farmer's perspective, the potential annual profit from producing switchgrass as a feedstock for energy production is:

(2) $SGNR_{s,tb,l} = \mathrm{Re}venue_{s,tb,l,w} - Cost_{s,tb,l,w} = SGR(Y_{s,w})_{l} - SGC(Y_{s,w})_{tb,l}$,

where s is soil type, tb is storage method (e.g., bales covered with a tarp on gravel), l is switchgrass production contract type offered by the biomass processor, w is weather 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 (tons/acre). Both return and cost depend on switchgrass yield SGY (dry tons/acre) which varies by soil type. The farm decision maker has two questions to address when deciding whether to produce switchgrass: (1) How much switchgrass should be produced? (2) What input combination should be chosen to produce the desired quantity of switchgrass? Depending on a farmer's 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:

$$\begin{aligned} SGR_{s,tb,l,w} &= PETH_{l,w} \times ETHY_{tb,l,w} \times SGY_{s,w} \\ &+ \sum_{m} PCOP_{l,m,w} \times COPY_{tb,l,m,w} \times SGY_{s,w} \\ &+ PCARB_{l,w} \times CARB_{l,w} \end{aligned} \quad (3)$$

where PETH is the price for ethanol ($/gal) produced from the switchgrass, ETHY is the yield of ethanol (gallon) 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), and CARB is the soil carbon stored by producing switchgrass (dry tons/acre).

Because switchgrass is a perennial crop, it is only planted once in a lifespan of ten years or more. 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:

$$
\begin{aligned}
SGC_{s,tb,l,w} &= EST(DFP)_{l,w} + NIT(DFP_w, NFP_w)_l + MOW(DFP_w)_l \\
&+ RAKE(DFP_w)_l + BALE(DFP, SGY_{s,w})_l + STAGE(DFP, SGY_{s,w})_l \\
&+ STORE(SGY_{s,w})_l + OTHER,
\end{aligned} \tag{4}
$$

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); and OTHER are the other costs of production that do not vary with s, tb, l, or w. The variables assumed to be random in equation (2) 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 that would be purchased in each year of production. Higher yields increase field time per acre to harvest and handle switchgrass, thus increasing fuel, labor, and other operating and ownership costs.

Rational farmers are assumed to maximize profit given their limited resources and available inputs and opportunities as well as their risk attitudes. These rational farmers first search for feasible enterprises to produce and then decide which mix and proportion of those enterprises should be implemented.

Simulation Analysis

The crop simulation model ALMANAC was used to generate crop, hay, and pasture yields for each production alternative on the representative farm for 100 years (Kiniry et al. 2005). The historical price data was used to produce a random set of correlated prices for corn, soybeans wheat, hay, switchgrass, lignin, corn stover, wheat straw, fertilizer, and diesel fuel for 100 years. The historical prices were placed in a cumulative distribution and the simulation model @Risk in Decision Tools (Palisade Corporation, 2007), which uses Monte Carlo simulation, simulated 100 years of correlated prices.

The simulated yields and prices were then used to determine the net return per acre via the following equation:

$$(6)\quad \begin{aligned} NR_C = \sum SCP \times SCY - [QN \times SNP + QF \times SFP + OVC + MDI + LC + \\ (QN \times SNP + QF \times SFP + OVC) \times IOC \times Year] \end{aligned}$$

where the summation sign allows for double cropping in a year, *SCP* is the simulated crop price, *SCY* is the simulated crop yield per acre, *QN* is the quantity of nitrogen recommended per acre, *SNP* is the simulated nitrogen price, *QF* is the quantity of fuel that is expected to be used per acre, *SFP* is the simulated fuel price, *OVC* is other variable costs that do not change from year to year, *MDI* is the machinery depreciation and interest expense, *LC* is labor costs, *IOC* is the interest rate on operating capital, and *Year* is the number of months in which capital is needed divided by 12 months. Enterprise budgets were used in net return construction (University of Tennessee, 2008a).

The cattle enterprise was modeled using the University of Tennessee's enterprise budget for a cow-calf enterprise. The extension budget has a 35 animal unit base which includes 30 cows, 5 replacement heifers, and a breeding bull. It was assumed that there was a 90% calf crop calved in February and March with a 2% death loss (University of Tennessee, 2008a). Cattle prices were simulated for steers, heifers, and cull/utility cows. For the cattle enterprise, steers and heifers were assumed to be sold in October while cull cows where assumed to be sold in May and the net returns per acre of land were expressed as:

$$(7)\ \ NR_{(cow-calf)} = \begin{bmatrix} K_S P_S AW_S + K_H P_H AW_H + K_U P_U AW_U \times DL - \\ (HC \times AU + \dfrac{(RPF - SPF)}{Ton} \times SHP + QN \times SNP + QF \times SFP + FC) \end{bmatrix} \div AC\ ,$$

where K_S is the number of steers sold fixed at 13, P_S is the price of a steer, AW_S is the average weight of steers sold fixed at 510 pounds, K_H is the number of heifers sold fixed at 9, P_H is the price of a heifer, AW_H is the average weight of heifers fixed at 465 pounds, K_U is the number of cull/utility cows sold fixed at 5, P_U is the price of a cull/utility cow, AW_U is the average weight of cull/utility cows sold fixed at 1000 pounds, *DL* represents a 2% death loss and is fixed at 98%, *HC* is the average cost of an animal unit excluding hay cost, nitrogen for pasture, and fuel cost, *AU* is the number of animal units fixed at 35, *RPF* is the total required forage for a 35 animal unit operation fixed at 296,380 pounds of dry matter, *SPF* is the simulated pounds of forage from ALMANAC, *Ton* is the conversion of pounds to tons fixed at 2,000 (1 ton is equal to 2000 pounds), *SHP* is the simulated price per ton of hay, *QN* is the quantity of nitrogen needed for 52.5 acres of pasture, *SNP* is simulated nitrogen price, *QF* is the quantity of fuel used for the cattle enterprise, *SFP* is the simulated fuel price, *FC* is fixed cost, and *AC* is the number of acres required for a 35 animal unit operation fixed at 52.5 acres.

The requirements for the average animal unit carried on the farm each year is based on the feed requirements for a 1,000 pound cow that weans a 510 pound steer and the forage availability as simulated in ALMANAC. The National Research Council (NRC) has determined that it takes approximately 22.6 pounds of dry matter per day from forage and hay for a 1,000 pound cow to wean a 497 pound steer so the adjusted feed requirements for weaning a 510 pound steer is 23.2

pounds of dry matter per day. On average, the forage must contain 53.325% total digestible nutrients (TDN) and 8.41% crude protein (CP) (NRC, 1996). This calculates to 8,468 pounds of dry matter from forage and hay per year for one animal unit and 296,380 pounds of dry matter from forage and hay per year for the 35 animal unit enterprise.

Prices for the beef cow industry were simulated using the @Risk simulation model in Decision Tools (Palisade Corporation, 2007) which uses Monte Carlo simulation. Historical prices for a 510 pound steer, 465 pound heifer, and a 1000 pound cull/utility cow were obtained from NASS for the state of Tennessee for the years 1975 through 2007 (U.S. Department of Agriculture-NASS). The historical prices were inflated to 2007 dollars and then put into a cumulative distribution function. Then @Risk (Palisade Corporatation, 2007) was used to simulate a 100 year distribution of net returns from the beef cattle enterprise. The simulated prices were then instituted into equation (7) to generate 100 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 that is being offered by the University of Tennessee Biofuels Initiative compensates the contractor with an annual $450/acre payment (University of Tennessee Contract, 2009). In order to receive full payment, producers must document and follow established production practices. The price can be adjusted annually based on positive changes in the U.S. 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 the year 2007 which was $2.24/gallon. The first year adjustment as a result of planting, weed control, and harvesting activities will be based on 40.65

gallons/acre of diesel while years two and three will 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 the University of Tennessee supplies the seed for all acres contracted to help offset establishment costs (University of Tennessee, 2009).

The Food, Conservation and Energy Act of 2008 (U.S. Congress, 2008) which establishes a Biomass Crop Assistance Program (BCAP) to encourage farmers to produce annual or perennial biomass crops in areas around biomass processing plants is another variation that could affect contract price. This act allows for the USDA to pay a contractor up to 75% of establishment costs during the first year as well as paying up to $45/dry ton of biomass for harvest, storage, and transport to a biorefinery (U.S. Congress, 2008). These terms could be rearranged which could change risk distribution and price per dry ton of biomass. These types of terms entice farmers to contract with energy companies because of the risk reduction that comes with many input costs being paid by the government or the energy company.

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. The expected revenue contract will be analyzed by itself as well as with BCAP provisions to offer another alternative.

A spot market price with no contract interference is a third option. The spot market price would be based on ethanol's energy equivalent price to gasoline. Simulated switchgrass prices will be generated based on projected prices per dry ton of switchgrass. An energy equivalent price series for switchgrass as an ethanol based energy substitute for gasoline will be constructed using historical wholesale gasoline price data that will be put into real terms by inflating the historical prices to 2007 dollars. The number of gallons of ethanol that can be produced per dry ton of switchgrass will be assumed to be 76 gallons for switchgrass (Wang, Saricks, and Santini, 1999; Larson et al., 2005). A net energy conversion factor of 1.8 will be used to derive net energy gallons/ton of switchgrass by processing of 33.8 gallons for switchgrass [((1.8-1)÷1.8) ×76] (Wang, Saricks, and Santini, 1999; Larson et al. 2005). Assuming an energy value of 76,000 BTUs per gallon of ethanol (Wang, Saricks, and Santini, 1999; Larson et al. 2005), the net energy gallons of ethanol produced for switchgrass will be multiplied by 76,000 to estimate the net BTUs per dry ton of switchgrass. The net energy values from ethanol are estimated to be 2.567 million BTUs per dry ton for switchgrass. The net energy BTUs per dry ton of switchgrass will be multiplied by the average Tennessee gasoline price per million BTUs to create a price series for switchgrass (Larson et al. 2005).

The base situations and contracts, as described previously, are the UT Biofuels Initiative, the BCAP, expected yield price, and the spot market. As presented above, the only revenue source being evaluated is revenue from ethanol production. Switchgrass also 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, which is a component of switchgrass that is not converted into ethanol. Carbon credits are a revenue source in that switchgrass has the ability to sequester carbon (Burras and McLaughlin, 2002) and the futures trading market of carbon dioxide on the Chicago Climate Exchange and the European Climate Exchange. Switchgrass has been found to store 1.79 tons of carbon dioxide per acre (McLaughlin and Walsh 1998) and 1.5 tons of carbon dioxide per acre (Burras and 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 et al. (1989) was used to identify the first-degree (FSD) and second-degree stochastic dominance (SSD) set of the traditional enterprises on the soil types analyzed. The FSD and SSD of the traditional enterprises were then reanalyzed in Goh et al.'s (1989) program to determine the FSD and SSD set from the top traditional enterprises and switchgrass contract alternatives, which included spot market, UT Biofuels Initiative, and BCAP provisions. Spot market and BCAP switchgrass had six 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), carbon credits from the European Climate Exchange (ECX), Elec and CCX, and Elec and ECX in addition to ethanol. UT Biofuels Initiative had a base revenue source from ethanol as well as CCX and ECX in addition to ethanol.

The FSD and SSD alternatives for the traditional enterprises, the switchgrass contract alternatives, and the base UT Biofuels Initiative and BCAP 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 yield price, a set price per dry ton of biomass based on an expected average yield, with no incentives as well as an expected yield price using BCAP that would dominate the top ranked alternatives that were previously analyzed at each $r(x)$.

Results and Discussion

Risk-Efficient Systems

The FSD and SSD generated data sets for traditional enterprises were corn for Dunmore and Dewey soils and beef cattle for Dandridge soil. The FSD data set for the dominating traditional enterprises and the switchgrass alternatives were corn, UTECX, and BCAPElecECX for Dunmore and Dewey soils while Dandridge soil only returned UTECX and BCAPElecECX. The SSD set for the second analysis was corn for Dunmore and Dewey soils and UTECX for Dandridge soil. Because the FSD and SSD sets for both previous analyses were small, UTNo (UT Biofuels Initiative base contract) and BCAPNo (BCAP base provisions) were added to all soil types to extend the analysis to include the current contracting opportunities.

Net return statistics are found in table 1. Corn maximized expected net returns for Dunmore ($129.62/acre) and Dewey ($128.06/acre) as well as producing the largest minimum net return for Dunmore ($-12.65/acre) and Dewey ($-12.30/acre). UTECX maximized the expected net return for Dandridge ($78.81/acre) as well as having the largest minimum net return ($-98.58/acre). BCAPElecECX provided the largest maximum for Dunmore ($519.42), Dewey ($496.41), and Dandridge ($334.53).

Ordering of Systems

The Riskroot computer program identified eight breakeven risk-aversion coefficients (BRAC) for the FSD and SSD set and selected alternatives for Dunmore and Dewey soils while it identified 6 BRACs for Dandridge soil. The ordering of alternatives from "most preferred" to "least preferred" for $r(x)$ values is influenced greatly by the level of absolute risk aversion. Corn and BCAPElecECX ranked first for both Dunmore and Dewey soils based on the absolute risk aversion level. Corn was in the SSD set for Dunmore and Dewey which implies that it ranked first for all risk averse decision behaviors. BCAPElecECX ranked first only for behavior that was risk seeking for Dunmore and Dewey. UTECX and BCAPElecECX ranked first for the Dandridge soil based on the level of absolute risk aversion. UTECX was in the SSD set for Dandridge, ranking it first for all risk averse decision makers while BCAPElecECX ranked first for most risk seeking behaviors for Dandridge soil.

Risk averse producers would likely benefit from growing corn if the soil type is either Dunmore or Dewey while a risk seeking producer may find it more advantageous to produce switchgrass under BCAP provisions with additional revenue sources of electricity and ECX carbon credits. Table 2 suggests that a producer who has Dandridge soil may be better off producing switchgrass for all levels of risk because the dominating traditional enterprise, beef, ranks no higher than fourth at any level of risk. The University of Tennessee contract with ECX carbon credits is suggested for risk averse producers and slightly risk seeking individuals while higher risk seeking producers may benefit more from BCAP provisions with electricity and ECX carbon. Traditional enterprises are competitive with switchgrass alternatives in higher yielding soils such as Dunmore and Dewey but the same enterprises are less competitive in Dandridge soil, a lower yielding soil type when compared to Dunmore and Dewey soils.

Table 3 compares the dominating alternative for each soil type from Table 2 and alternatives that have a price for switchgrass that is based on an expected yield. The additional alternatives were constructed to determine what price per ton of switchgrass would dominate the dominant alternative from Table 2. The most risk averse decision maker with Dunmore soil would have to receive BCAPECX60, which includes BCAP provisions, European carbon credits, and $60/dry ton for switchgrass, or 85ECX, which is $85/dry ton and European carbon credits, to change from corn production to switchgrass production. The most risk seeking decision maker with Dunmore soil would have to receive 90ECX, which is $90/dry ton and European carbon credits, or BCAPECX35, which includes BCAP provisions, European carbon credits, and $35/dry ton for switchgrass, to change from switchgrass production under BCAP provisions with electricity and European carbon credits as additional revenue sources (BCAPElecECX) to one of the aforementioned systems. The dominating systems for Dunmore soil range from 70ECX to 90ECX and from BCAPECX30 to BCAPECX60.

The most risk averse decision maker with Dewy soil would have to receive 85ECX or BCAPECX55 to change from corn production to switchgrass production. The most risk seeking decision maker with Dewey soil would have to receive 90ECX or BCAPECX35 to change from BCAPElecECX to one of the aforementioned systems. The dominating systems for Dewey soil range from 70ECX to 90ECX and from BCAPECX30 to BCAPECX55.

The most risk averse decision maker with Dandridge soil would have to receive 75ECX or BCAPECX35 to change from UTECX, switchgrass production under the University of Tennessee Biofuels Initiative contract with European carbon credits, to one of the previously mentioned switchgrass production alternatives. The most risk seeking decision maker with Dandridge soil would have to receive 95ECX or BCAPECX35 to change from BCAPElecECX to one of the aforementioned systems. The dominating systems for Dandridge soil range from 75ECX to 95ECX and from BCAPECX30 to BCAPECX35.

The dominant traditional enterprise for Dunmore and Dewey soil, corn, shows an ability to be competitive with switchgrass alternatives. 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 compete 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.

Summary and Conclusions

This paper 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. The results for the more productive soils suggest that all risk averse producers would benefit most from corn production while risk seeking individuals may benefit more from switchgrass production under BCAP provisions with additional revenue sources of electricity and carbon. Switchgrass was ranked first for all decision makers in the less productive soil, Dandridge, but the contract terms differ based on risk behavior. The results suggest risk averse producers would benefit from producing switchgrass with the UT contract with additional revenue from carbon while some risk seeking producers would receive more benefit from BCAP with electricity and carbon.

Switchgrass appears to be a feasible alternative for producers in the contracting region for all soil types. 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.

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Table 1. Net Revenue Statistics for FSD and Selected Alternatives for All Soils

			Net Revenue ($/Acre)			
Soil Type	Alternative[a]	Risk Efficiency Criteria[b]	Mean	Standard Deviation	Maximum	Minimum
Dunmore	Corn[c]	FSD and SSD	129.62	58.06	289.89	-12.65
	UTNo		11.41	135.12	192.40	-236.29
	BCAPNo		-21.62	119.22	387.33	-181.62
	UTECX	FSD	53.09	136.01	226.89	-191.71
	BCAPElecECX	FSD	48.14	135.50	519.42	-141.54
Dewey	Corn[c]	FSD and SSD	128.06	58.20	290.44	-12.30
	UTNo		9.21	130.11	188.83	-243.55
	BCAPNo		-22.26	116.19	367.45	-181.32
	UTECX	FSD	50.89	131.31	225.94	-197.55
	BCAPElecECX	FSD	47.61	132.07	496.41	-141.24
Dandridge	Beef[c]		11.39	63.22	220.16	-168.78
	UTNo		37.14	74.62	164.28	-139.41
	BCAPNo		-39.39	88.12	226.55	-188.17
	UTECX	FSD and SSD	78.81	75.19	222.36	-98.58
	BCAPElecECX	FSD	27.32	100.32	334.53	-140.45

[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, BCAP = Biomass Crop Assistance Program, ECX = European Carbon Exchange credits, and Elec = electricity). All switchgrass alternatives include ethanol as a source of revenue.
[b] FSD = first-degree stochastic dominance set. SSD = second-degree stochastic dominance set
[c] FSD and SSD of traditional enterprises.

Table 2. 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
Dunmore	0.025748	Corn	BCAPElecECX	**BCAPNo**[c]	**UTECX**	UTNo
	0.008552	Corn	BCAPElecECX	UTECX	**BCAPNo**	**UTNo**
	0.003004	Corn	**BCAPElecECX**	**UTECX**	UTNo	BCAPNo
	-0.002616	Corn	**UTECX**	**BCAPElecECX**	UTNo	BCAPNo
	-0.007033	**BCAPElecECX**	**Corn**	UTECX	UTNo	BCAPNo
	-0.009400	BCAPElecECX	Corn	UTECX	**UTNo**	**BCAPNo**
	-0.014930	BCAPElecECX	Corn	**UTECX**	**BCAPNo**	UTNo
	-0.016856	BCAPElecECX	**BCAPNo**	**Corn**	UTECX	UTNo
Dewey	0.026798	Corn	BCAPElecECX	**BCAPNo**	**UTECX**	UTNo
	0.008814	Corn	BCAPElecECX	UTECX	**BCAPNo**	**UTNo**
	0.002591	Corn	**BCAPElecECX**	**UTECX**	UTNo	BCAPNo
	-0.002081	Corn	**UTECX**	**BCAPElecECX**	UTNo	BCAPNo
	-0.007179	**BCAPElecECX**	**Corn**	UTECX	UTNo	BCAPNo
	-0.009142	BCAPElecECX	Corn	UTECX	**UTNo**	**BCAPNo**
	-0.014949	BCAPElecECX	Corn	**UTECX**	**BCAPNo**	UTNo
	-0.017658	BCAPElecECX	**BCAPNo**	**Corn**	UTECX	UTNo
Dandridge	0.029385	UTECX	**BCAPElecECX**	**UTNo**	Beef	BCAPNo
	-0.003217	UTECX	**UTNo**	**BCAPElecECX**	Beef	BCAPNo
	-0.010872	**UTECX**	**BCAPElecECX**	UTNo	Beef	BCAPNo
	-0.013959	BCAPElecECX	UTECX	UTNo	**BCAPNo**	**Beef**
	-0.021419	BCAPElecECX	UTECX	**BCAPNo**	**UTNo**	Beef
	-0.037091	BCAPElecECX	UTECX	BCAPNo	**Beef**	**UTNo**

[a] Rounded to six decimal places.
[b] Refer to table 1 footnote a.
[c] Boldface denotes the stategies where dominance switches at the BRAC

Table 3. Expected Yield Price's Dominance at the Breakeven Risk-Aversion Coefficients (BRACs)

		Ordering of Alternatives[b]		
Soil Type	BRAC[a]	1	2	3
Dunmore	0.025748	BCAPECX60[c]	85ECX[c]	Corn
	0.008552	80ECX	BCAPECX50	Corn
	0.003004	BCAPECX40	75ECX	Corn
	-0.002616	BCAPECX35	75ECX	Corn
	-0.007033	BCAPECX30	70ECX	BCAPElecECX
	-0.009400	75ECX	BCAPECX35	BCAPElecECX
	-0.014930	75ECX	BCAPECX35	BCAPElecECX
	-0.016856	90ECX	BCAPECX35	BCAPElecECX
Dewey	0.026798	85ECX	BCAPECX55	Corn
	0.008814	80ECX	BCAPECX45	Corn
	0.002591	75ECX	BCAPECX35	Corn
	-0.002081	BCAPECX35	75ECX	Corn
	-0.007179	70ECX	BCAPECX30	BCAPElecECX
	-0.009142	BCAPECX35	75ECX	BCAPElecECX
	-0.014949	BCAPECX35	85ECX	BCAPElecECX
	-0.017658	90ECX	BCAPECX35	BCAPElecECX
Dandridge	0.029385	75ECX	BCAPECX35	UTECX
	-0.003217	BCAPECX30	75ECX	UTECX
	-0.010872	BCAPECX30	75ECX	UTECX
	-0.013959	BCAPECX30	80ECX	BCAPElecECX
	-0.021419	BCAPECX30	85ECX	BCAPElecECX
	-0.037091	BCAPECX35	95ECX	BCAPElecECX

[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. BCAPECX60 is BCAP provisions plus European carbon credit and $55/ton of switchgrass and 85ECX is $85/ton of switchgrass plus European carbon credit.