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# *Risk, Infrastructure and Industry Evolution*

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# Risk and Uncertainty at the Farm Level

James A. Larson[1]

## Introduction

The United States has a growing focus on reducing dependence on petroleum and encouraging the production of fuels from renewable sources. The Energy Independence and Security Act of 2007 have mandated that 36 billion gallons per year of ethanol be produced in the United States by 2022, with 21 billion gallons per year from feedstocks other than corn (U.S. Congress, 2007). Perlack *et al*. (2005) and English *et al*. (2006) estimate that more than a billion tons of lignocellulosic feedstock could be produced annually for ethanol production in the United States. With the more aggressive goal, lignocellulosic materials such as switchgrass, corn stover, wheat straw, and wood waste products would be needed to fill the gap (De La Torre Ugarte, English, and Jensen, 2007).

While the lignocellulosic biomass-to-ethanol industry is not yet commercially viable, the U.S. Department of Energy has set a goal for its research and development efforts to make lignocellulosic ethanol cost competitive with petroleum by 2012 (U.S. Department of Energy, Office of the Biomass Program, 2008). Substantial research dollars have been allocated by federal, state, and private entities towards making lignocellulosic conversion technologies commercially viable. Currently, several projects are being planned to demonstrate the feasibility of biomass-to-ethanol technologies. For example, Dupont Danisco and The University of Tennessee using private, as well as State and Federal funding, are jointly planning to operate a pilot lignocellulosic biorefinery using corn stover and switchgrass as feedstocks (The University of Tennessee, 2008a, 2008b). The University of Tennessee Biofuels Initiative contracted with 16 farmers in spring 2008 to plant 723 acres of switchgrass to provide feedstock to the plant. The biorefinery is scheduled to be operational in December 2009.

Switchgrass may have certain advantages as a dedicated perennial energy crop because of its wide adaptation and ecological diversity in the United States (McLaughlin *et al*., 1998). In addition, switchgrass may be a more efficient way to produce renewable energy than with corn production. Schmer *et al*. (2008) in a study of production on 10 switchgrass fields on marginal cropland in three Midwest Sates found that switchgrass produced 540 percent more renewable than nonrenewable energy used in the production of the feedstock. However, compared to other agricultural commodities, transportation costs from the grower to a biorefinery for biomass crops such as switchgrass may be relatively high due to its bulkiness and low energy densities. Thus, the relatively high transportation costs for biomass feedstocks may result in a more locally-grown market situation for biomass feedstock. Epplin *et al*. (2007) has suggested that the development of a biomass-to-ethanol industry using dedicated energy crops may follow one of two paths. One possible direction is a vertically integrated system where the biorefinery leases (or purchases) lands and directly manages the production, harvest, storage, and transportation of feedstocks. Another alternative for the processing plant is to enter into long-term production and harvest contracts with individual local farmers. Under this market scenario, the processor likely will have an interest in providing production contracts or other incentives to induce farmers to supply sufficient feedstocks to keep the plant operating at capacity.

A number of researchers have evaluated the economic feasibility of using lignocellulosic feedstocks for bioenergy and bioproduct production including McCarl, Adams, and Alig (2000); Dipardo (2001); Haq (2001); Bernow, Dougherty, and Dunbar (2000); and English, Menard, and De La Torre Ugarte (2004). In addition, numerous studies have estimated the cost of producing energy crops in the United States, including Downing *et al*. (1996); Duffy and Nanhou (2001); Graham *et al*. (1995); Johnson and Baugsund (1990); Mooney *et al*. (2008); Perrin *et al*. (2008); Vadas, Barnett, and Undersander (2008); Vaughan, Cundiff, and Parrish (1989); and Walsh *et al*. (1998).

Not understood as well is how the emerging industry of interrelated feedstock producers, biorefineries, and auxiliary service providers, such as transportation and storage, will be

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structured and how each will bear and/or share business and financial risks. Analyses by Bhat, English, and Ojo (1992); Cundiff (1996); Cundiff and Marsh (1996); Cundiff, Dias, and Sherali (1997); Epplin (1996); Thorsell *et al.* (2004); Bransby *et al.* (2005); Sokhansanj, Kumar, and Turhollow (2006); Mapemba *et al.* (2007); Kumar and Sokhansanj (2007); and Popp and Hogan (2007) have evaluated some of the aspects of the costs and risks of harvest, storage, and transportation of biomass feedstocks. A biomass-based energy industry may have a very different set of business and financial risks than for coal and oil industries. For example, severe drought and flood events are not uncommon in the United States, can cover large geographic areas, and may have substantial negative impacts on production. Thus, as with other agricultural commodities, weather and the growth and development characteristics of biomass crops may have very large impacts on the quantity and quality of biomass produced for energy production in any one year, and on the storage, transportation, production decisions for the biorefinery. Thus, an important aspect of risk for the industry will be with on-farm production of bioenergy crops.

If perennial switchgrass is to be used as a feedstock for ethanol production, it will need to compete with other crop and livestock activities in terms of expected profit and the variability of profit (risk). Thus, the unique growth and development characteristics of a perennial biomass feedstock such as switchgrass may influence its risk and return tradeoffs with other farming activities. In addition, the logistics of harvest, storage, and transport of switchgrass may affect risk and return for a producer. The objective of this paper is to explore some of the potential on-farm business and financial risks that may be associated with producing a dedicated bioenergy crop such as perennial switchgrass.

## Potential Sources of Risk

As defined by Robison and Berry (1987), risk happens when the uncertain outcome of a choice made by a decision maker alters the well-being of that decision maker. Risk is usually thought of in terms of variation around the expected outcome or in terms of deviations below the expected outcome. From a risk standpoint, farmers are most often concerned about the probability of incurring low net revenues, in addition to the expected net revenue, when considering the adoption of a new agricultural technology or enterprise. Farmers typically face both business and financial risks when making production, marketing, and financial decisions. The five major sources of business risk in agriculture are: 1) production or technical risk, 2) market or price risk, 3) technological risk, 4) legal and social risk, and 5) human sources of risk (Sonka and Patrick, 1984). Production risks include precipitation, temperature, wind, pest, fire, and theft events that can negatively impact yields, production, and income. Price risk can occur for both crop inputs purchased and crop outputs sold. Technological risk arises from the potential of a current investment to be diminished by technological improvements that may occur in the future. Legal and social risk can arise from several sources. These include changing government policies and risks associated with legal contracts for debt and for the purchase of inputs and the marketing of outputs. Human sources of risk are often related to the labor and management functions of the firm. By contrast, financial risk relates to the farmers' ability to bear risks using liquidity (e.g., cash reserves), leverage (i.e., the proportion of the firm's assets financed with owner equity and debt obligations), leasing, and insurance as risk management tools (Barry and Baker, 1984).

Because switchgrass is a perennial crop, it only needs to be planted once in a lifespan of ten years or more. The potential factors that may influence the on-farm business and financial risks associated with perennial switchgrass production are outlined based on two key points in the lifecycle of the stand: 1) establishment (years 1-3) and 2) the annual harvest and storage of the crop.

### Establishment (Years 1-3)

The first key stages of switchgrass establishment are seed germination, emergence, and development of the root system (Smart and Moser, 1999). Switchgrass can be difficult to establish because of seed dormancy, soil moisture and temperature conditions with spring planting, and weed competition (Rinehart, 2006). Particularly in upland varieties, freshly harvested seed have a high percentage of dormant seeds that can be reduced by properly aging the seeds for up to one year (Guretzky, 2007). Seedling growth is best at temperatures between 75°F and 85°F and thus is best established when soil conditions are warm and moist in the spring (Guretzky, 2007). Weeds such as crabgrass germinate more readily in cooler soils than can switchgrass and can provide serious competition during establishment (Rinehart, 2006). Thus, weed control during the establishment phase is critical. Effective herbicides to control weeds (particularly other grasses) in switchgrass have not yet been labeled for switchgrass. However, weeds may also be controlled in the establishment year by clipping them above the growing switchgrass to prevent seed production (Rinehart, 2006). Research has shown that expected switchgrass yields are similar across seeding rates but that low seeding rates may increase variability of yields during the establishment phase (Mooney *et al.*, 2008). Weed control may be a more critical factor during establishment especially with lower seeding rates.

The University of Tennessee Biofuels Initiative contracted with 16 farmers to plant 723 acres of switchgrass in spring 2008 to supply feedstock to a pilot biorefinery scheduled to operational in 2009 (The University of Tennessee, 2008a). Of the total switchgrass area planted spring 2008, 164 acres (23 percent) were replanted in 2008 because of a lack of soil moisture for germination and emergence due to drought conditions (Garland, 2008). Soil moisture problems may have been particularly acute on soils where switchgrass was planted after winter wheat. University of Tennessee Extension personnel managing the project believe there is a possibility of replanting another 144 acres (20 percent) in 2009 because of establishment problems.

Typically, it takes three years for switchgrass to reach its full yield potential after establishment (Walsh, 2007). Mooney *et al*. (2008) reported that first- and second-year switchgrass yields across several landscapes and soil types in an experiment at Milan, TN, averaged 14- and 60-percent of third-year yields. Harvest can still be conducted in the first two years after establishment, though some experts recommend not harvesting the crop in the first year to allow more root establishment to take place (Walsh, 2007).

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 biorefinery. As the planting of switchgrass is ramped up to meet the potential demand from biorefineries, seed prices may jump because of the time needed to expand seed stocks, further exacerbating establishment costs. Producers who have production contracts shorter than the lifespan of the stand may find themselves holding an asset that does not have value if the contract is not renewed. The market for switchgrass may be limited to bioenergy production though there may be limited uses of the crop as hay and pasture. Because the perennial switchgrass stand is a durable asset that lasts more than one year, it may be subject to technological risk in that newer, higher yielding varieties may be developed before the end of the useful life of the stand. The traditional uses of switchgrass have been for feeding cattle, anchoring soil, restoring grasslands, and providing wildlife habitat. Other more limited potential uses include a material for low quality fiber board, paper, and as a base for growing mushrooms. There is likely to be tremendous potential for variety improvement of switchgrass with traits geared toward producing ethanol (i.e., maximizing dry matter production and enhancing conversion-to-ethanol properties) rather than traditional uses.

Another potential source of risk is for farmers primarily dependent on leased land. Because switchgrass is a perennial that may be under contract for a number of years, and requires fewer inputs after establishment than many annual crops, landowners may opt to manage the switchgrass themselves using custom input application and harvest services. Thus, a potential reduction in land area that can be leased for other crop production may increase rents in a given area. Rising rents may potentially increase production costs for farmers not growing switchgrass. In addition, producers unable to rent as much land as they are accustomed to may not be able to spread their fixed costs over as large a crop area and thus may increase financial risks.

### Harvest and Storage

For bioenergy production, the projected harvesting time for switchgrass is once in the fall after a killing freeze (Rinehart, 2006). After a freeze, nutrients move into the root system, minimizing the harvest of nutrients and their replacement, and maximizing the lignocellulosic material for conversion to ethanol. The coarse and fibrous switchgrass harvested after a killing freeze may increase repair and maintenance costs of equipment and reduce the lifespan of equipment compared with other forage-type materials. Reported yields of switchgrass vary between 1 and 16 tons per acre (Rinehart, 2006). With the large amount of biomass to be harvested, machine and labor time per unit of crop area will likely increase at an increasing rate for each additional ton harvested, thus machinery and labor costs will likely be higher for switchgrass (Cundiff, 1996). In addition, higher precipitation in the fall and winter months may limit field days and increase harvest times and biomass losses relative to other potential harvest periods (Hwang and Epplin, 2007).

The projected ethanol production capacity of a commercial sized biorefinery using lignocellulosic feedstocks is about 50 million gallons per year—half the size of a typical biorefinery that used corn grain as its feedstock (Port, 2005). A biorefinery of this size using switchgrass as a feedstock would require between 1,520 (90 gallon of ethanol per ton conversion rate) and 1,950 (70 gallons per ton conversion rate) tons per day of material to supply the plant. This translates into 554,800 to 711,750 tons of biomass to be processed per year. Assuming large rectangular bales placed in 32 foot high stacks, a storage yard of over 100 acres would be needed to store the annual production needs of a 50 million gallon per year plant (Womac and Hart, 2008). Given that switchgrass will likely be harvested only once-a-year and yields will vary from year-to-year because of weather, the logistics of storage and transportation of the feedstock will be critical.

The once-a-year harvest, coupled with the large area required to store switchgrass, will likely require storage of a substantial amount of biomass away from the plant on the farm. Precipitation and weathering may affect the quality and dry matter losses of bales delivered to the plant and thus the yield of ethanol from a ton of switchgrass (Wiselogel *et al*., 1996; Sanderson, Egg, and Wiselogel, 1997). In addition, the weight of bales transported to the biorefinery may be influenced by the level of exposure to precipitation while being stored on the farm. In a study by English, Larson, and Mooney (2008), uncovered round bales of switchgrass after 100 days of outside storage showed a 5 to 10 inch area of weathering along the bale's outer edge, and bale weights increased an average of 117 lbs/bale. Uncovered on-farm storage may increase transportation costs to the biorefinery as well, especially in areas that have high precipitation such as the southeastern and midsouth areas of the United States. Thus, a processor may require that stored bales be protected from precipitation and weathering. In addition, large numbers of switchgrass bales under storage may be a fire hazard and present liability issues for the farmer. Who pays for the on-farm protection and storage of the crop—the farmer or the biorefinery? All of the aforementioned issues affect risk and return, and thus the potential willingness and ability of farmers to produce switchgrass for bioenergy production.

## Risk Management and Switchgrass Production

### Potential Risk Management Benefits

Notwithstanding the potential risks of producing switchgrass, it may also provide some potential risk management and risk diversification benefits after the establishment phase. Switchgrass requires less water than most crops currently cultivated because of a deep and extensive root system (Bransby *et al*., 1989). Switchgrass requires about 25 inches or less of water per season, compared to 26 inches for corn and 39 inches for cotton (Brouwer and Heibloem, 1986; Stroup *et al*., 2003; Smith, 2007). Thus, switchgrass is more drought resistant than other crops (Bransby *et al*., 1989) and may provide higher yields than many annual crops in drought years. In wet springs when planting of annual crops may be difficult or impossible, switchgrass may reduce the probability of a crop failure due to weather because it is planted only once every 10 or more years. Switchgrass may tolerate very wet conditions during the growing season better than many annual crops and thus may provide higher yields. In addition, switchgrass requires less pesticides and fertilizers than most crops currently grown in the United States (Bransby *et al*., 1989; Rinehart, 2006). Nitrogen fertilizer requirements are generally less than for corn averaging 40 to 80 pounds of nitrogen to produce one acre of switchgrass compared with 100 to 200 pounds of nitrogen to produce an acre of corn grain.

### Prior Risk Management Research

Several studies have evaluated the potential risk and returns to biomass crop production. Lowenberg-DeBoer and Cherney (1989) simulated yields, costs, and net revenues of switchgrass in Indiana based on weather, fertilizer, time of harvest, and a constant output price. They found that applying little or no nitrogen and harvesting the grass after maturity was the risk efficient management for switchgrass production.

Larson *et al*. (2005) developed a farm-level risk programming model based on yield and price variability to evaluate the ability and willingness of farmers to provide biomass feedstocks for a northwest Tennessee 2,400 acre grain farm. They found that the opportunity to diversify the farm crop enterprise mix through biomass production using a marketing contract by a processor may improve mean net revenues and reduce the variability of net revenues. The production of switchgrass provided positive risk management benefits to the farm while the production of wheat straw and corn stover did not. However, at the higher contract prices, additional labor resources would be needed by the representative farm to allow more production of biomass. Thus, a contract design might need to include provisions for harvesting and hauling services to be provided by the processor in addition to a guaranteed price.

Larson, English, and He (2008) and He, Larson, and English (2008) evaluated the risk management benefits of several potential contract types that could be used reduce the risk of switchgrass production. The four potential types of contracts analyzed in this study offer different levels of biomass price, yield, and production cost risk sharing between the representative farm and the processor. Results indicate that a contract price above the energy equivalent price in a spot market type contract would be needed to induce biomass production on the representative farm. A contract that makes annual payments based on the expected biomass yield over the life of the contract rather than on annual yield induced the largest amount of production (primarily switchgrass) under risk aversion. Because of the price and yield protection offered with this type of contract, biomass production was generally induced at lower contract prices.

### United States Government Biomass Risk Management Programs

The recently-passed Food, Conservation and Energy Act of 2008 (U.S. Congress, House of Representatives, 2008) establishes a Biomass Crop Assistance Program (BCAP) to encourage farmers to produce annual or perennial biomass crops in areas around biomass processing plants. Producers can contract with the USDA to receive biomass crop payments of up to 75 percent of establishment costs during the first year. Subsequent annual payments then offset the so-called "lost opportunity costs" until the dedicated energy crops are fully established and begin to provide farmers with revenue. In addition, the BCAP program provides for cost-share payments up to $45 per dry ton for the harvest, storage, and transport of biomass crops to a processing plant. Eligible participants for the BCAP program include producers located within a “project area” defined as an economically viable distance from a biomass processing plant. Contracts with the BCAP program will run for five to ten years depending on the type of biomass crop grown. Producers will also be required to contract with a biomass-to-energy conversion facility to receive payments.

### University of Tennessee Biofuels Initiative Risk Management Programs

The Governor of Tennessee signed legislation in 2007, establishing the Tennessee Biofuels Initiative (University of Tennessee, 2008a, 2008b). This initiative teams the University of Tennessee with an industrial partner to construct a lignocellulosic ethanol conversion research and commercial facility. The University of Tennessee partnered with Dupont Danisco to select a site near Vonore in East Tennessee south of Knoxville (The University of Tennessee, 2008b). The biorefinery will utilize corn stover and switchgrass as a feedstock. As part of the initiative, three-year contracts to grow switchgrass for the plant were offered to 16 farmers on 723 acres with a set payment of $450 per acre per year. To receive the full annual payments after harvest, farmers are required to follow and document a set of prescribed production practices. Farmers were given seed to partially offset the costs of establishing the switchgrass stand. In addition, to help farmers manage input price risk, budgeted energy costs were converted to diesel fuel equivalents and contract payments for switchgrass production were tied to the change in the diesel fuel price based on the last week of October 2007 U.S. Energy Information Agency published price levels. Farmers are responsible for harvest and on-farm bale handling and storage. The contract has the biorefinery being responsible for loading and hauling the switchgrass from the contractor's property to the biorefinery.

## Case Study

The potential impacts of weather and input prices on the distribution of yields and production costs for switchgrass grown as a feedstock for energy production are explored in this section. In addition, the potential impacts that the 2008 Food, Conservation and Energy Act BCAP planting and harvest payments described previously may have on the distribution of production costs were evaluated.

Yields and production costs for two contrasting agricultural soils in Tennessee were used for the evaluation (USDA-NRCS, 2005). Loring soils are commonly found in West Tennessee and are moderately well drained with slopes ranging from 0 to 20 percent. Crops typically grown on Loring soils include corn, cotton, soybeans, and wheat. Dandridge soils are found in East Tennessee and are shallow, excessively drained, and have slopes ranging from 2 to 70 percent. Agricultural uses include pasture and hay for beef cow-calf production.

### Methods and Data

Switchgrass production costs (SGC) include establishment expenses incurred in the first year of production and recurring annual costs for nutrients, pest control, and harvest and storage and can be modeled using:

$$\textbf{(1)}\quad \mathrm{SGC}_{i,j,t} = \mathrm{EST}(\mathrm{DFP})_j + \mathrm{NIT}(\mathrm{DFP}_t,\mathrm{NFP}_t) + \mathrm{HERB}(\mathrm{NFP}_t) + \mathrm{MOW}(\mathrm{DFP}_t)_j + \mathrm{RAKE}(\mathrm{DFP}_t)_j + \mathrm{BALE}(\mathrm{DFP}_t,\mathrm{SGY}_{i,t})_j + \mathrm{STAGE}(\mathrm{DFP}_t,\mathrm{SGY}_{i,t})_j + \mathrm{STORE}(\mathrm{SGY}_{i,t})_j + \mathrm{OTHER} + \mathrm{RRL}_i,$$

where *i* is soil type, *j* is switchgrass production incentive offered by the biomass processor, and *t* is production year; EST is switchgrass establishment expenses amortized either over the life of a contract to produce switchgrass or over the expected life of the stand ($/acre); NIT is nitrogen fertilization costs; MOW, RAKE, BALE, STAGE, and STORE are the labor, operating, and ownership costs of mowing, raking, baling, handling, and storing switchgrass ($/acre); OTHER are the other costs of production that do not vary with *i*, *j*, or *t* ($/acre); and RRL is the rental rate (opportunity cost) on land ($/acre). The variables assumed to be random in equation **(1)** were diesel fuel price (DFP, $/gal), nitrogen fertilizer price (NFP, $/lb), and switchgrass yields (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 ownership costs.

A 100 year distribution of switchgrass production costs was simulated for each soil type using equation **(1)**. The variables treated as random in the simulation were switchgrass yield, nitrogen fertilizer price, diesel fuel price, and machine time for harvesting and handling switchgrass as a function of yield. The ALMANAC crop model (Kiniry *et al*., 1992) was used to generate random switchgrass yields for the Loring and Dandridge soils. A 100 year set of prices for nitrogen fertilizer and diesel fuel were simulated using the @Risk simulation model in Decision Tools (Palisade Corporation, 2007). Price data for estimating the nitrogen fertilizer and diesel fuel distribution parameters for @Risk were obtained using 1977 through 2005 prices reported in Agricultural Statistics (USDA-NASS, 1977 through 2007 Annual Issues). Prices were inflated to 2007 dollars by the Implicit Gross Domestic Product Price Deflator (Council of Economic Advisors, 2008) before estimating probability density function parameters using the Best Fit model in Decision Tools (Palisade Corporation, 2007).

Switchgrass production costs were estimated using budget parameters produced by The University of Tennessee Department of Agricultural Economics (Gerloff, 2008; Mooney *et al*., 2008; English, Larson, and Mooney, 2008). Establishment costs were amortized over an assumed contract period of five years and treated as an annualized cost in the simulation. Nitrogen fertilization was assumed constant at the Extension recommended level of 60 lb nitrogen/acre. The Extension budget only recommends that phosphorous and potassium be applied on deficient soils and thus it was assumed that none was applied in the simulation. Farmers were assumed to be responsible for harvest, which included all machinery, labor, and materials expenses for mowing, raking, baling, bale handling, and on-farm storage. The contract assumes the biorefinery was responsible for loading and hauling the switchgrass from the contractor's property to the biorefinery.

Mowing and raking costs remained constant on a per-acre basis for all yield levels in the simulation. Machine and labor time and twine for the baling and handling operations were assumed to be a function of yield. To accomplish this, the capacity of the large round baler was assumed to be 5.5 tons per hour (i.e., one hour of machine time with a 5.5 ton yield). Bale handling also was assumed to operate at a rate of 6 tons per hour (Mooney *et al*. 2008). Bales were assumed to be stored under a tarp on a gravel pad. Materials and labor costs to construct the pad and annual labor and other costs to affix the tarp to the bales annually were from English, Larson, and Mooney (2008). Gravel pad and tarp costs were based on the largest expected yield over the simulation for each soil type. The useful lives of the tarp and pad with no salvage value were assumed to be five years, the same length as the contract for switchgrass. Land rental (opportunity) costs assumed were $68/acre for crop land (Loring soil) and $20/acre for pasture land (Dandridge soil) (Tennessee Department of Agriculture, 2008).

The effects of University of Tennessee Biofuels Initiative and BCAP type planting and harvest incentives on switchgrass production costs were evaluated for each soil type. The three incentive scenarios evaluated were: 1) no incentives, 2) an establishment incentive to reduce planting costs, 3) a harvest incentive to reduce harvest, handling, and storage costs, and 4) a combination of the establishment and harvest incentive. For the planting incentive, total budgeted machinery, materials, and labor costs for planting were reduced by up to 75 percent and amortized over the assumed contract period of five years. For the harvest incentive, the estimated on-farm harvest, handling, and storage costs were reduced by up to a maximum of $30/ton in the simulation. If harvest and handling costs were less than $30/ton, the lower cost was used to calculate the amount of cost reduction with the incentive. The harvest incentive scenario assumes that $15/ton of the subsidy would be allocated to the transport of bales from the farm to the biorefinery.

## Results and Discussion

On the East Tennessee Dandridge soil, switchgrass yields averaged 5.7 tons/acre and varied between 2 and 11.2 tons (Table 1). By comparison, yields averaged 9.1 tons/acre and varied between 1.7 and 15.6 tons on the more productive West Tennessee Loring soil (Table 1). There was a 39 percent chance that yields on the Dandridge soil would be 5 tons/acre or less compared with a 25 percent probability on the Loring soils (Figure 1). Results indicated that switchgrass production was more risky because of a higher frequency of low yields on the Dandridge soil when compared with the Loring soil.

Assuming no production incentives, total switchgrass production costs per acre were lower on the East Tennessee Dandridge soil than on the West Tennessee Loring soil. On the Dandridge soil, total production costs averaged $389/acre and ranged from $288/acre to $562/acre (Table 1). By comparison, the average cost of producing switchgrass on the Loring soil was 26 percent more at $523/acre. About two-thirds of total costs for each soil type came from harvest, handling, and storage activities (Table 1). Larger harvest costs because of higher yields coupled with a higher opportunity cost on land contributed to higher production costs on a land-area basis for the Loring soil. Notwithstanding the lower total costs on a land-area basis, the average cost per ton was higher on the Dandridge soil than on the Loring soil. Dandridge soil production costs averaged $75/ton and varied between $45/ton and $150/ton (Table 1). By contrast, Loring soil production costs averaged $71/ton and

Table 1. Simulated Switchgrass Yields and Production Costs for Two Contrasting Tennessee Soils Assuming No Production Incentives

| Soil Type | Unit | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Loring: | | | | | |
| Yield | tons/acre | 9.1 | 3.9 | 1.7 | 15.6 |
| Harvest Cost[a] | $/acre | 345 | 103 | 159 | 527 |
| Total Cost | $/acre | 523 | 104 | 338 | 711 |
| | $/ton | 71 | 34 | 43 | 203 |
| Dandridge: | | | | | |
| Yield | tons/acre | 5.7 | 2.1 | 2.0 | 11.2 |
| Harvest Cost[a] | $/acre | 260 | 57 | 161 | 424 |
| Total Cost | $/acre | 389 | 58 | 288 | 562 |
| | $/ton | 75 | 23 | 45 | 150 |

[a] Mowing, raking, baling, handling, and storage machinery, materials, and labor costs

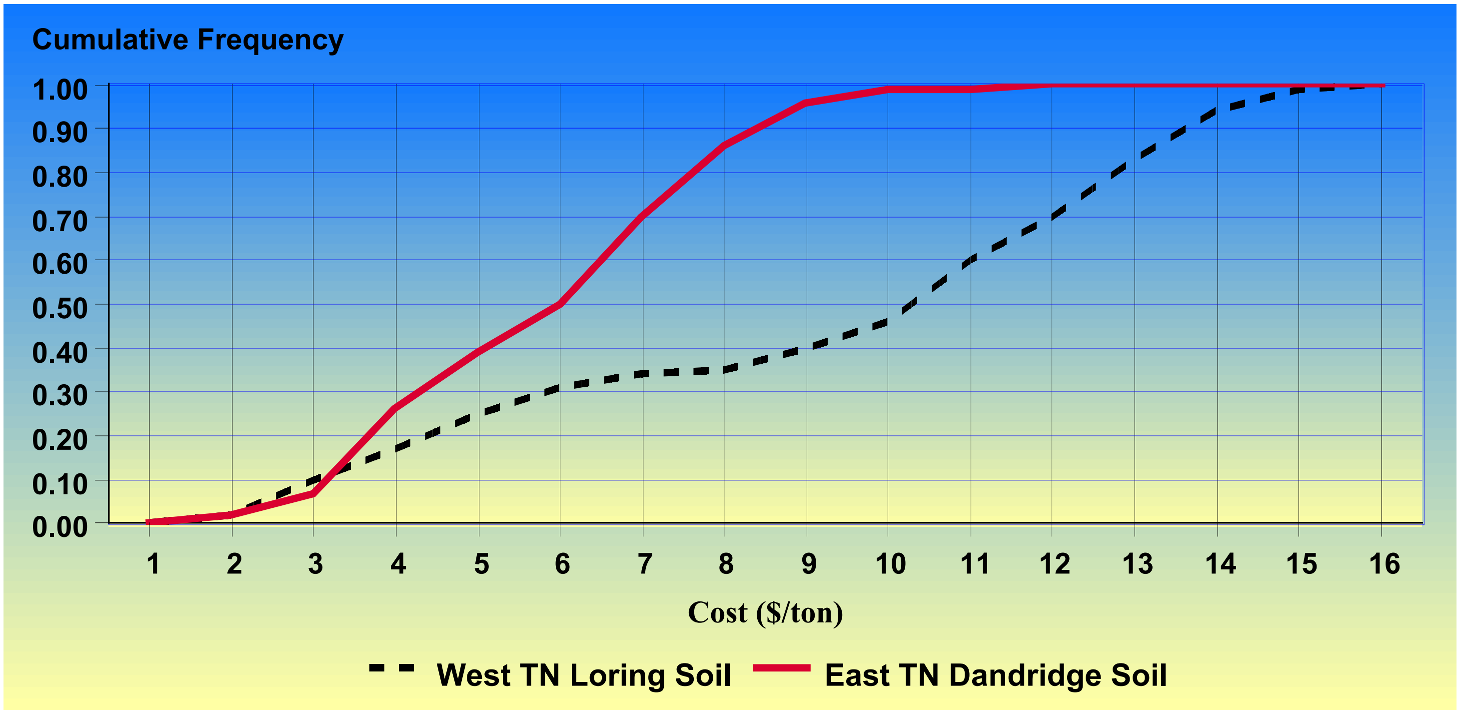

**Figure 1.** Probability Distribution of Yields for Switchgrass Grown as a Dedicated Energy Crop for Two Contrasting Tennessee Soils

fluctuated between $43/ton and $203/ton (Table 1). For production costs less than $100/ton, the Loring soil had a higher probability of producing a lower per ton cost than the Dandridge soil (Figure 2). For example, the frequency of total production costs being $60/ton or less was 64 percent for the Loring soil compared with only 32 percent for the Dandridge soil (Figure 2).

The distribution of production costs for each soil type also can be used to evaluate the frequency of positive net revenues for a given switchgrass price that might be paid by

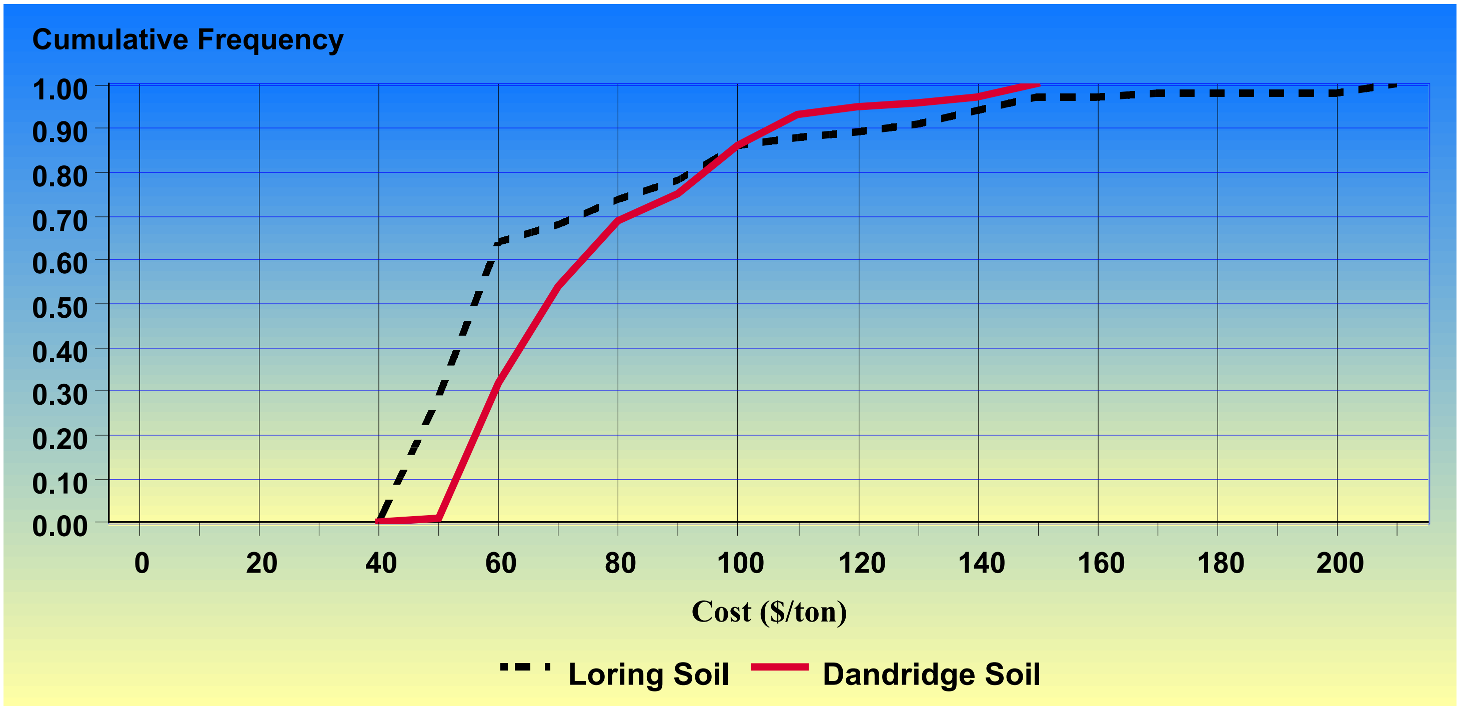

**Figure 2.** Probability Distribution of Total Production Costs ($/ton) for Switchgrass Grown on Two Contrasting Tennessee Soils Assuming No Production Incentives

the biorefinery to a farmer. For example, the frequency of net revenues greater than zero is 64 percent for the Loring soil but only 32 percent for the Dandridge Soil at a $60/ton biomass price. Generally larger yields over which to spread production costs contributed to the higher frequency of a lower cost per ton of producing switchgrass on the more productive Loring soil. The results suggest that production costs per ton are lower and the frequency of a positive net revenue for a given switchgrass price might be higher in West Tennessee than in East Tennessee.

The 75 percent cost share for establishing switchgrass reduced mean production costs by 12 percent to $62/ton on the Loring soil and 14 percent to $64/ton on the Dandridge soil (not shown). The $30/ton harvest payment had a larger impact on production costs than the planting establishment payment. The $30/ton harvest cost share reduced mean production costs by 43 percent to $41/ton on the Loring soil and 40 percent to $45/ton on the Dandridge soil (not shown). With both payments, the chance of achieving a production cost of $60/ton or less increased from 64 percent to 87 percent on the Loring soil (Figure 3). The impact of the establishment and harvest payments on the frequency of obtaining production costs of $60/ton or less was greater on the Dandridge soil, jumping from 32 percent to 91 percent (Figure 4). Results indicate that the planting establishment and harvest cost share payments had a larger impact on the frequency of attaining lower production costs on the more marginal East Tennessee Dandridge soil than on the more productive West Tennessee Loring soil.

## Summary and Conclusions

This paper evaluated some of the potential on-farm business and financial risks that may be associated with producing switchgrass as a dedicated bioenergy crop. The potential sources of risk based on the growth and development characteristics of perennial switchgrass and weather were identified. Difficulties in establishing the switchgrass stand and low yields the first three years after establishment and the harvest, storage, and transportation of feedstocks as affected by weather presents significant risk management challenges for both farmers and processors.

A simulation case study evaluated the potential impact that weather and input-price risk might have on the distributions of production costs for switchgrass on two contrasting Tennessee soil types. The Loring soil is located in West Tennessee and is more productive than the Dandridge soil in East Tennessee. In addition, the impacts of the Biomass Crop Assistance Program (BCAP) risk management tools specified in the Food, Conservation, and Energy Act of 2008 on the distribution of switchgrass net revenues for the two soil types were evaluated.

Results indicated that switchgrass production was more risky on the Dandridge soil because of a higher frequency of low yields. Generally smaller yields over which to spread production costs contributed to the lower probability of

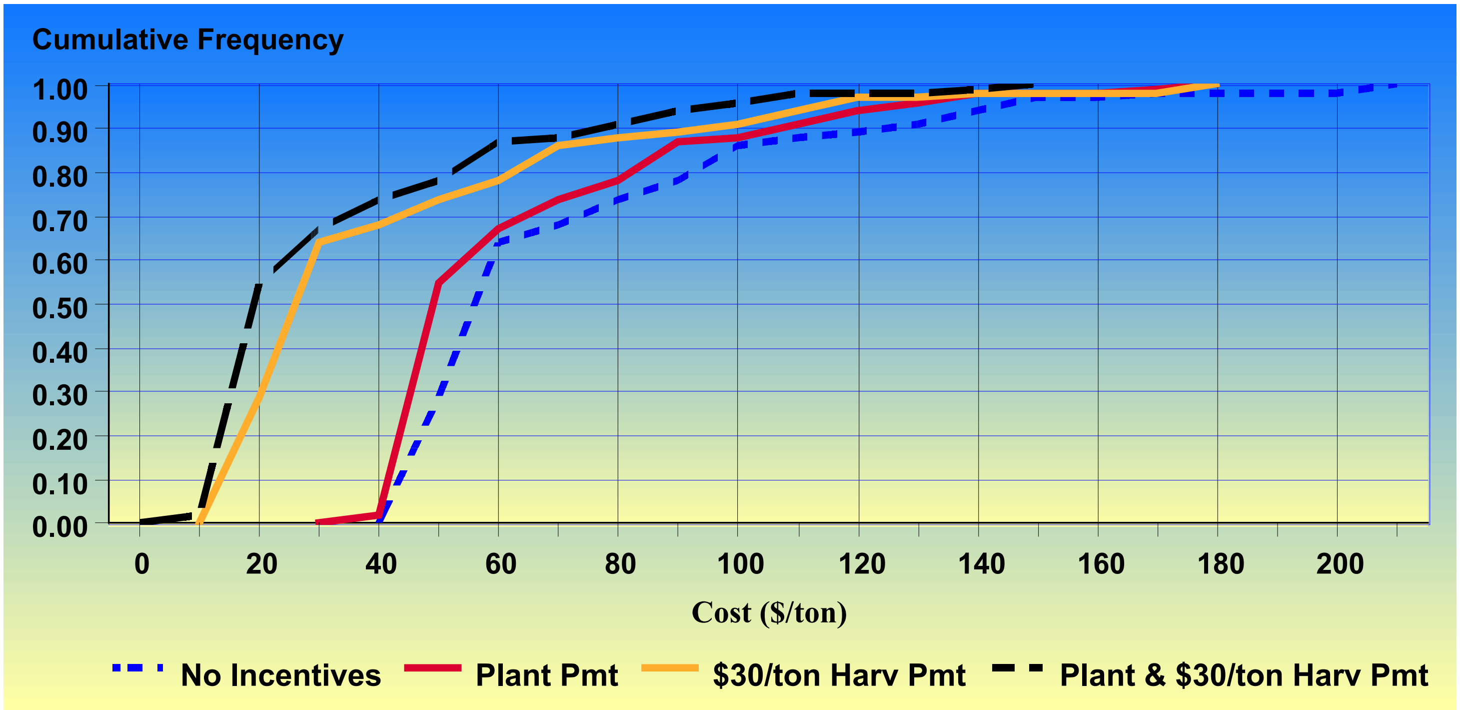

**Figure 3.** Probability Distributions of Production Costs for Switchgrass Grown on a West Tennessing Loring Soil Assuming No Cost Incentives (No Incentive), a Switchgrass Establishment Cost Incentive (Plant Pmt), a Switchgrass Harvest Cost Incentive ($30/ton Harv Pmt), and an Establishment and Harvest Cost Incentive ($30/ton Plant & Harvest Pmt)

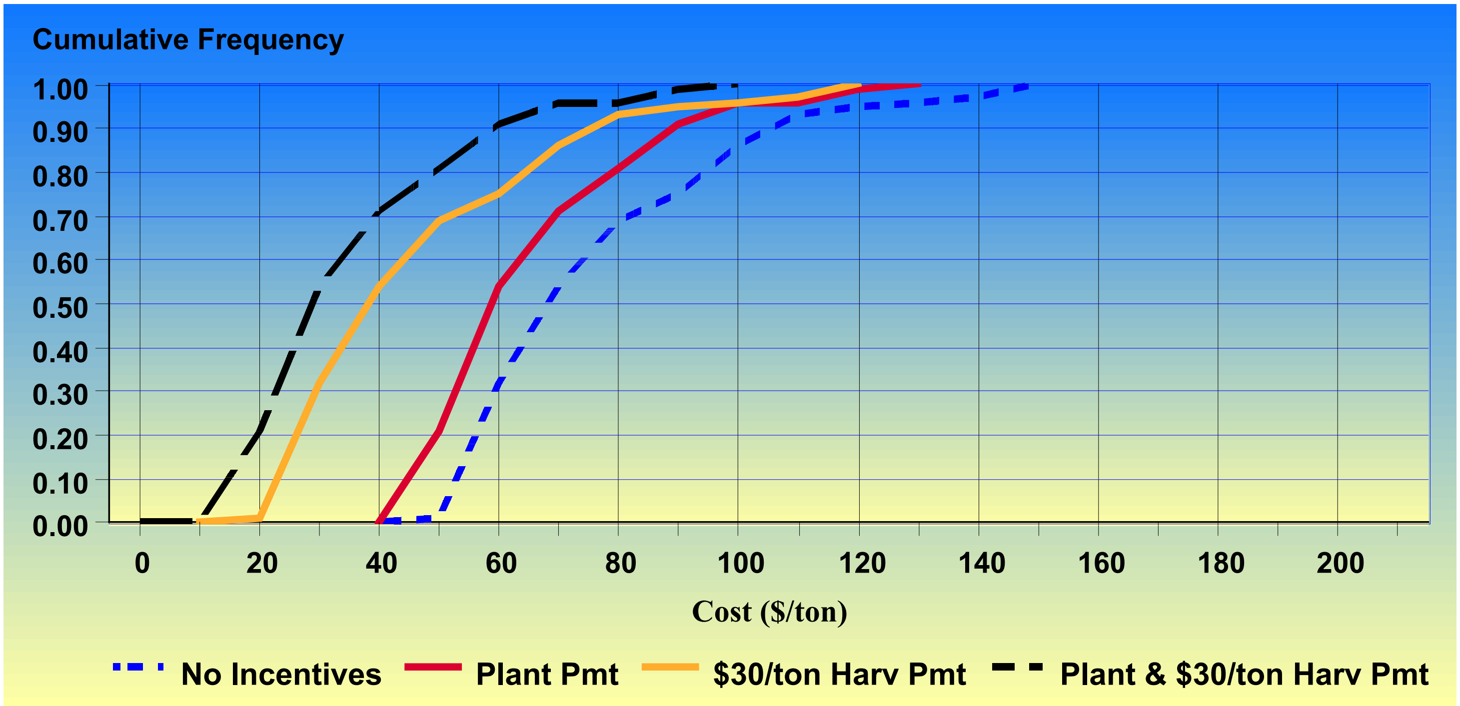

**Figure 4.** Probability Distributions of Production Costs for Switchgrass Grown on an East Tennessing Dandridge Soil Assuming No Cost Incentives (No Incentive), a Switchgrass Establishment Cost Incentive (Plant Pmt), a Switchgrass Harvest Cost Incentive ($30/ton Harv Pmt), and an Establishment and Harvest Cost Incentive ($30/ton Plant & Harvest Pmt)

having a lower cost per ton on the more marginal Dandridge soil relative to the Loring soil. Thus, for a given switchgrass price, the probability of a positive net revenue might be higher for the Loring Soil because of lower production costs per ton than for the Dandridge soil. In addition, the BCAP planting establishment and harvest cost share payments had a larger impact on frequency of attaining lower production costs on the more marginal Dandridge soil than on the more productive Loring soil. Thus, policymakers and other decision makers may want to target BCAP payments to more marginal lands to maximize the potential soil erosion, water quality, and other benefits of growing switchgrass.

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