A Farm-Level Evaluation of Conditions Under Which Farmers Will Supply Biomass Feedstocks for Energy Production

James A. Larson, Associate Professor
Department of Agricultural Economics
The University of Tennessee
Knoxville, Tennessee 37996-4518
Phone: (865) 974-7231
Fax: (865) 974-4829
E-mail: jlarson2@utk.edu

Burton C. English, Professor
Department of Agricultural Economics
The University of Tennessee
Knoxville, Tennessee 37996-4518
Phone: (865) 974-7231
Fax: (865) 974-4829
E-mail: benglish@utk.edu

Chad Hellwinkel, Research Associate
Agricultural Policy Analysis Center
The University of Tennessee
Knoxville, Tennessee 37996-4519
Phone: (865) 974-7234
Fax: (865) 974-7298
E-mail: chellwin@utk.edu

Daniel De la Torre Ugarte,
Associate Professor
Agricultural Policy Analysis Center
The University of Tennessee
Knoxville, Tennessee 37996-4519
Phone: (865) 974- 7407
Fax: (865) 974-7298
E-mail: danieltu@utk.edu

Marie Walsh, Adjunct Associate Professor
Department of Agricultural Economics
The University of Tennessee
Knoxville, Tennessee 37996-4518
Phone: (865) 974-7231
Fax: (865) 974-4829
E-mail: mwalsh2@utk.edu

Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, RI, July 24-27, 2005

Abstract: This study evaluated the risk management potential of including biomass crops as a diversification strategy for a grain farm in northwest Tennessee. Results indicate that adding biomass crops to the farm enterprise mix could improve mean net revenues and reduced net revenue variability.

A Farm-Level Evaluation of Conditions Under Which Farmers Will Supply Biomass Feedstocks for Energy Production

Introduction

The U.S. currently consumes about 97 Quads of primary energy annually, and imports over 60 percent of its crude oil consumption. Petroleum consumption and total primary energy use are projected to increase to 56.6 and 139.1 Quads respectively by 2025 (U.S. DOE, 2003). U.S. interest in alternative energy sources is increasing as the economic, environmental, and energy security impacts resulting from continued reliance on fossil fuels (oil, coal, natural gas) are more fully recognized.

U.S. net agricultural income has varied substantially over the past decade with an average of $48.2 billion (1994-2003) and a variance of $6.7 billion. Income ranged from a low of $35.3 billion (2002) to a high of $57.8 billion (1996) (USDA-ERS, 2003). The agricultural sector is seeking new, higher value products to replace bulk commodity production and enhance farm income. The development of new, biobased industries offers potential new markets for agricultural producers as suppliers of biomass feedstocks.

Biomass feedstocks (e.g., starch from corn and oil from soybeans; cellulosic materials such as forestry and mill residues, urban wood wastes, dedicated energy crops, and agricultural crop residues) can be used to produce bioenergy (e.g., electricity or liquid transportation fuels such as ethanol) and bioproducts (e.g., adhesives, solvents, plastic precursors, and other organic compounds). Bioenergy and bioproduct markets could be large and could increase farm income, jobs, and economic growth in rural areas. Numerous studies estimate the cost of producing energy crops in the U.S. Examples include Cundiff (1996), Downing (1996), Duffy (2001), Graham (1995), Johnson (1990), Lindsey (1998), Vaughan (1989) and Walsh (1998). De La Torre Urgarte, et al. (2003) determine the potential impact that a biomass industry would have on the nation's agricultural sector. Other studies estimate the potential for bioenergy and bioproduct markets in the U.S. under a variety of market and policy scenarios. Duffield, (1998), Evans (1997), FAPRI (2001), Raneses (1996), Urbanchuk (2001), and USDA-OCE (2002) among others, examined the use of traditional agricultural crops (starch from corn grain, soybean oil) as feedstocks for bioenergy and bioproducts. Bernow (2002), DiPardo (2001), English (2004 a,b), Haq (2001), McCarl (2000), and Synapse Energy Economics (2000) evaluated the use of cellulose feedstocks (including crop residues and energy crops) as bioenergy and bioproduct feedstocks. All of the studies were conducted at a county, state, regional, or national level. These regional and national biomass feedstock supply studies estimate that substantial quantities of biomass could be available at less than $40/dry ton (dt).

Biomass feedstock markets will differ from traditional commodity markets in that they will more likely be local in nature. This is because biomass feedstocks are bulky and have low energy densities which results in high transportation costs. Thus, the development of biobased industries, at least initially, will hinge on the local availability of sufficient, cost competitive biomass feedstocks. Bioenergy and bioproduct markets could be large and could increase farm income, jobs, and economic growth in rural areas.

The development of biobased industries, at least initially, will hinge on the local availability of sufficient, cost competitive biomass feedstocks. It is envisioned that the local market will consist of a single user facility that contracts with local farmers to provide biomass feedstocks. Given the high cost of constructing a user facility, the principal 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. Supplying biomass feedstocks will require changes in the way farmers manage their operations. The ability of farmers to respond to the market will be constrained by on-farm economic, structural, and resource constraints (e.g., time constraints, equipment constraints, land ownership, farm size, production activities (i.e., crop, livestock), soil type and topography, etc.). The willingness of farmers to provide biomass feedstocks will be a function of biomass feedstock profits, variability of profits, and correlation of profits relative to traditional crop profits. These factors will vary with respect to the contractual incentives offered by the user facility. An understanding of the factors that will affect farmer decisions to supply biomass feedstocks is needed. This study will examine the significance and interaction of on-farm constraints, biomass supply variability, and contractual arrangements on farmer decisions to supply biomass feedstocks. The information gained is crucial to identifying barriers and finding solutions to supplying sufficient, cost effective feedstocks to support developing biobased industries and will aid in improving estimates of the potential size and cost of developing biobased industries than is currently possible.

The objective of this paper is to evaluate the ability and willingness of farmers to provide biomass feedstocks given their on-farm situation and potential contractual arrangements with user facilities. The specific farm situation evaluated in the present analysis is a grain and oilseed farm operation in northwest Tennessee.

Methods and Data

Representative Farm

A farm-level quadratic programming model for a representative grain farm in Weakley and Obion Counties in northwest Tennessee was developed for the analysis. A panel of northwest Tennessee farmers, with assistance from University of Tennessee Extension personnel, used consensus building methods to describe the farm size and crop enterprise characteristics of a typical farm in northwest Tennessee (Tiller, 2001). The 2,400 acre farm produces corn, soybeans, and wheat. The specific crop rotations and soils for the farm were derived from the USDA-NRCS soil survey database (USDA-NRCS, 2005).

The crop enterprises and rotations assumed for the representative farm were continuous corn, continuous soybeans, continuous winter wheat, a soybean-corn rotation, and a soybeans-wheat double-crop enterprise. The 2,400 acre farm was assumed to have three major soil types common to northwest Tennessee: Collins (0% slope with no fragipan), Memphis (1% slope with 42" depth to fragipan), and Loring (3% slope with 30" depth to fragipan). In general, the Collins and Memphis soils are the most productive and the Loring soil is the least productive. The representative farm was assumed to have 1,200 acres of Collins soils, 528 acres of Loring soils, and 672 acres of Memphis soils. The major tillage practice in northwest Tennessee is no tillage and was used to simulate yields and estimate production costs for all crop activities on the farm (Tennessee Department of Agriculture, 2004).

The representative farm was assumed to have the opportunity to provide biomass feedstocks to a local single-user facility that produces ethanol. The farmer was assumed to have three energy crop production alternatives: corn stover, wheat straw and switchgrass. Thus, the representative farmer had the choice between producing corn grain only or corn grain and corn stover. Similarly, the representative farmer could choose to produce wheat grain only or wheat grain and wheat straw.

Quadratic Programming Model

The quadratic programming model objective function was:

(1) $$Maximize\ Z = U'X - \lambda X'\sigma X,$$

subject to

(2) $$AX \leq B, \text{ and}$$

(3) $$X \geq 0.$$

where Z was the value of the objective function ($), U was the expected net revenues ($/acre) for each crop activity on each land type, X was the acres for each crop activity on each land type, λ was the absolute risk aversion coefficient, σ was the net revenue variance-covariance matrix, A was the resource requirements, and B was the resource restrictions.

The two main resource constraints specified in the model were for soil type and labor. Total land was restricted to 2,400 acres and land for each soil type was restricted to 1,200 acres of Collins soils, 528 acres of Loring soils, and 672 acres of Memphis soils. Six bimonthly labor periods were specified in the model. Labor requirements by period were from crop budgets by Gerloff (2005) and updated bioenergy crop budgets by Walsh (1996). Labor availability by period was for a family of four (Johnson, 1991). Total family labor availability by period was 510 hours for January-February, 510 hours for March-April, 675 hours for May-June, 705 hours for July-August, 585 hours for

September-October, and 585 hours for November-December. In addition to family labor, it was assumed that the farm could hire an additional 2,000 hours of labor per year at \$8.50/hour (Gerloff, 2005). Hired labor was assumed to have an efficiency of 90% in the model to account for the extra management time for the farm operator (Musser et al., 1984).

Net Revenues

Net revenues for each year between 1977 and 2001 were constructed using 1977 through 2001 yield and crop price data. Net revenues for the corn, soybean, wheat, soybean-corn rotation, and soybean-wheat double crop enterprisers were estimated using the following budget equation:

(4) $$NR = P \times Y - VC - FC,$$

where P is crop price (\$/bu), Y is crop yield (bu/acre), VC is the variable costs of production (\$/acre), and FC is the fixed costs of production (\$/acre). Net revenues for switchgrass production (NR_{SG}) were estimated using:

(5) $$NR_{SG} = (BCP - BTC) \times CP \times EBY + (BPM - BTC) \times (BY - EBY) - VC - FC,$$

where BCP is the biomass crop contract price (\$/dt) offered by the local biomass conversion facility; BTC is the cost of transporting the biomass from the edge of the field to the conversion facility (\$/dt); CP is the proportion between 0 and 1 of expected biomass yield, EBY (dt), that is contracted to be delivered to the user-facility; BPM is the biomass price based on its energy value as a substitute for gasoline in the production of ethanol; and BY is the actual biomass yield realized.

Equation (5) represents a forward contracting mechanism (Musser et al., 1984) that could be used to provide an incentive for farmers to supply a certain quantity of biomass to the user facility. While it assumes that the user-facility will buy all of the biomass produced by the farmer, it also provides for a penalty if there is a shortfall in promised production. For example a farmer could contract 50% of expected biomass production. If the biomass yield exceeds the contract level, the gross revenue is the sum of receipts from the contracted biomass yield times the contracted price plus the yield above the contracted yield times the current price of the biomass as an energy substitute for gasoline in ethanol production. In years when realized yields are below the contracted level, the farmer does not have enough biomass to satisfy the contract. The farmer pays a penalty to the biomass user for the shortfall that is equal to the difference between the actual yield and the contracted yield times the current price as an energy substitute for gasoline. Similarly, net revenues for the corn-stover (NR_{CS}) and wheat-straw enterprises (NR_{WS}), where both grain and biomass are produced and sold, were calculated using the following net revenue equations:

(6) $$NR_{CS} = P \times Y + (BCP - BTC) \times CP \times EBY + (BPM - BTC) \times (BY - EBY) - VC - FC,$$

and

(7) $$NR_{WS} = P \times Y + (BCP - BTC) \times CP \times EBY + (BPM - BTC) \times (BY - EBY) - VC - FC.$$

Corn, soybean, wheat, and soybean-wheat production costs were derived from University of Tennessee Extension budgets (Gerloff, 2005). Switchgrass production costs were estimated using BIOCOST, a full economic production cost model developed by Oak Ridge National Laboratory (Walsh, 1996) and recently updated to include the latest recommended switchgrass management practices and expected yields. The switchgrass budget assumes that perennial switchgrass stand was replanted every 10 years with the replanting costs amortized over the 10 years. The costs of harvesting corn stover and wheat straw (additional machinery ownership, materials, and labor costs) along with the costs of additional nutrients removed with the biomass also were estimated using BIOCOST. All three biomass crops were assumed to be harvested using a large round bale system with the bales being moved to the edge of the field before transport to the user facility. The cost of transporting the biomass to the biomass conversion facility was assumed to be \$10/dt (English et al., 2004). Labor for all production activities on the farm was charged out using a wage rate of \$8.50 per hour (Gerloff, 2005).

Typically, historical yield estimates are used to generate information about expected yields and the potential variability of those yields. Generally speaking, however, this type of information is not readily available for a specific crop on a specific soil as required for this analysis. Therefore, simulation of crop yields is needed.

Crop growth simulation models can be applied to evaluate the relationship between crop productivity and selected environmental factors. There are several models including EPIC (Williams et al, 1989), CERES (Ritchie et al, 1989), and SOYGRO (Jones et al, 1989). In many cases these crop models have been developed in particular localities and are designed to simulate the growth of one crop. In this case, multiple crops are requiring simulation and to maintain consistency among simulated yield and for ease of operation, EPIC was selected as the crop growth simulator.

The Environmental Policy Integrated Climate model (EPIC) is a daily time step model that simulates the physical processes involved in hydrology, nutrient cycling, and plant growth simultaneously and realistically using readily available inputs. EPIC can simulate more than 80 crops and has been used to evaluate the crops and crop rotations required in this paper—continuous corn, soybeans, and wheat; along with a corn soybeans rotation, double crop soybeans-wheat, corn with corn stover removal, wheat with wheat straw removal, and a perennial crop, switchgrass. Each of these crops/crop rotations was evaluated for Loring, Memphis, and Collins soils using 1977 to 2001 weather data from the University of Tennessee Research and Education Center at Milan, TN (U.S. Department of Commerce, 1977-2001). Corn stover and wheat straw yields were calculated using 45% of the difference between the biomass yield and the grain yield predicted in EPIC (Nelson et al., 2004). The tillage practice assumed was no-tillage, consistent with the dominant practice in West Tennessee, and the inputs used and specified for the model were those specified in Tennessee Extension budgets developed by Gerloff (2004) and updated bioenergy crop budgets by Walsh (1996).

Tennessee average yearly corn, soybean, and wheat prices for 1977 through 2001 were used to calculate net revenues for each year for each cropping activity (Tennessee Department of Agriculture, 1978-2002). These prices were inflated to 2000 dollars by the Implicit Gross Domestic Product Price Deflator (U.S. Congress, Council of Economic Advisors, 2005). The inflated crop prices then were detrended using procedures described by Pelletier (2002) to remove the long-term downward trend in real crop prices. Mean 1977 through 2001 crop prices for the analysis were $2.00/bu (standard deviation of $0.75/bu) for corn, $3.80/bu (standard deviation of $1.49/bu) for soybeans, and $2.83/bu (standard deviation of $0.83/bu) for winter wheat. Because government program payments have been decoupled from farm production decisions, crop prices and net revenues were not adjusted for these program revenues in the analysis.

The end use for the biomass produced by the representative farm was assumed to be the production of ethanol. Energy equivalent price series for switchgrass, corn stover, and wheat straw as an ethanol based energy substitute for gasoline (BPM in equations 6, 7, and 8) were constructed using wholesale gasoline price data for 1977 through 2001. The number of gallons of ethanol that can be produced per dry ton of biomass was assumed to be 69.2 gallons for wheat straw, 72 gallons for corn stover, and 76 gallons for switchgrass (Wang et al., 1999). A net energy conversion factor of 1.8 was used to derive net energy gallons per ton of biomass after processing of 30.8 gallons for wheat straw [((1.8-1)÷1.8) ×69.2], 32.0 gallons for corn stover [((1.8-1)÷1.8) ×72], and 33.8 gallons for switchgrass [((1.8-1)÷1.8) ×76] (Wang et al., 1999). Assuming an energy value of 76,000 BTUs per gallon of ethanol (Wang et al., 1999), the net energy gallons of ethanol produced for each biomass product was multiplied by 76,000 to estimate the net BTUs per ton of biomass. The net energy values from ethanol per ton of biomass were estimated to be 2.337 million BTUs per dry ton for wheat straw, 2.432 million BTUs per dry ton for corn stover, and 2.567 million BTUs per dry ton for switchgrass. The net energy BTUs per dry ton of biomass for each crop was multiplied by the average Tennessee gasoline price per million BTUs for 1977 through 2001 (U.S. DOE, 2005) to create a price series for each biomass crop. Before creating the biomass price series, gasoline prices were inflated to 2000 dollars by the Implicit Gross Domestic Product Price Deflator (U.S. Congress, Council of Economic Advisors, 2005). Mean 1977 through 2001 biomass crop prices for the analysis were $27.45/dt (standard deviation of $6.38/dt) for wheat straw, $28.56/dt (standard deviation of $6.64/dt) for corn stover, and $30.14/dt (standard deviation of $7.01/dt) for switchgrass.

Analysis

A base set of risk efficient crop enterprises in the absence of biomass crops for five levels of absolute risk aversion were generated using the quadratic programming model. The base solution was then compared with the opportunity to provide biomass crops to the user facility under alternative forward contract price scenarios. The first scenario assumes that none of the biomass crops were forward priced with the user facility. The biomass price received by the farmer was assumed to be based on its energy equivalent value as a substitute for gasoline in ethanol production using 1977 through 2001 gasoline prices. The nine other scenarios represent three alternative forward contract price levels and three alternative forward contract yield levels for each biomass crop alternative. The three forward contract price levels were $30/dt, $32.50/dt, and $35.00/dt. Contract prices for corn stover and wheat straw were multiplied by 0.95 and 0.91, respectively, to reflect the lower BTU content of these two materials relative to switchgrass. The three forward contract yield levels evaluated with the model were 50%, 75%, and 100% or expected yield. The portion of yield not contracted was priced at the energy equivalent value of ethanol as a substitute for gasoline

Results and Discussion

The base LP solution that does not consider risk is presented in the first column of Table 1. The profit maximizing farm plan in the absence of biomass crop alternatives was to produce 1200 acres of soybeans and 1,200 acres of corn on all crop acreage using the soybeans-corn rotation. Lower production costs because of reduced nitrogen fertilization for corn after the nitrogen-fixing soybean crop made the soybeans-corn rotation the most profitable alternative for the farm. Mean farm net revenues for the base scenario was $98,562 or an average of $41/acre across the three soil types on the farm. Net revenues were lowest on the Collins soil, averaging $20/acre, and highest on the Memphis and Loring soils, averaging $50/acre and $49/acre, respectively. The standard deviation of net revenues for the farm was $234,552. Parameterization of the programming model to include absolute risk aversion ranging from 0.000001 to 0.000005 did not change the risk efficient crop mix from the base profit maximizing solution. No other combination of crop enterprises on the three soil types provided a more favorable risk-return tradeoff. In this case, the most profitable crop enterprise was the least risky.

Optimal farm plan results when biomass crops are a production option using biomass prices based on gasoline energy equivalent values when producing ethanol with the biomass also are presented in Table 1. Under this scenario, biomass prices average $27.45/dt (standard deviation of $6.38/dt) for wheat straw, $28.56/dt (standard deviation of $6.64/dt) for corn stover, and $30.14/dt (standard deviation of $7.01/dt) for switchgrass. The profit maximizing solution was to produce the soybean-corn rotation on the Collins and Loring soils (528 and 1,200 acres respectively) and to produce the corn-stover combination (486 acres) and switchgrass (186 acres) on the Memphis soil. An average of 2,906 dt of biomass would be supplied by the representative farm under this scenario. Mean farm net revenues rose by 6.6% ($6, 529) over the no energy crop base solution. In addition, the standard deviation of net revenues was reduced by 15% ($35, 143) from the base no bioenergy crop scenario.

For farmers who are risk averse, the optimal crop mix on the Memphis soil was to produce all switchgrass. In addition, switchgrass came into the crop mix on the lower productivity Collins soil at the two highest levels of absolute risk aversion (0.000003 and

0.000004). Depending on the level of risk aversion, between 6,458 and 7,694 dt of switchgrass was produced on average by the representative farm. More biomass tonnage was provided than under net revenue maximization because of the greater production per acre with switchgrass than with corn stover. Results indicate that a market for biomass based on energy equivalent prices for ethanol as a substitute for gasoline could provide Tennessee grain farmers with risk management benefits through the opportunity to diversify its crop mix. Switchgrass provided a more favorable risk-return tradeoff than the corn-stover production combination for risk averse farmers. Finally, the wheat-straw combination was not a risk efficient alternative for all of the risk aversion levels evaluated.

Forward contracting 50% or 75% of expected production at a price of $30/dt did not provide any risk management benefits over not contracting (results not shown). The crop enterprise mix for these two forward contracting scenarios was exactly the same as the no contract scenario for all absolute risk aversion levels. On the other hand, contracting 100% of expected production at $30/dt did provide a favorable risk-return tradeoff for the more risk averse decision makers (0.000003 and 0.000004) [Table 2]. At the higher risk aversion levels, switchgrass was produced on part of the Loring soil in addition to the production on the Memphis soil. In general, a guaranteed price set at about the average energy price equivalent on 50 to 100% of expected production did not induce greater production of biomass crops over the variable price strategy on the representative farm. Results indicate that higher contract prices are needed to induce biomass production on the acreage of the representative grain farm in the Loring soils.

Optimal farm plan results for the biomass production scenario where 50% of expected production was contracted at $32.50/dt are presented in Table 3. Under net revenue maximization, raising the guaranteed price by $2.50/dt made producing all switchgrass on the Memphis soil the most profitable option. Total biomass supplied by the farm averaged 6,268 dt, an increase of 116% (3,362 dt) over the no forward contract scenario. However, no biomass crops were produced on the Collins and Loring soils of the farm even with the higher price guarantee. Mean net revenue for the farm jumped by 11% ($10,795) and the standard deviation of net revenues plummeted 42.3% ($99,301) from the base no energy crop scenario. Increasing the amount of expected biomass production contracted from 50% to 100% at a price of $32.50/dt still did not induce any switchgrass production on the Loring soil under net revenue maximization (Table 4). However, average farm net revenues were 6.1% ($6,645) larger when the amount contracted was increased from 50% to 100% at a guaranteed price of $32.50/dt.

An important factor influencing the lack of switchgrass on the Loring soil acreage at the higher $32.50/dt price for all contract production levels was the differences in yields among soil types. Simulated switchgrass yields were the highest on the Memphis soil, averaging 9.33 dt/acre (standard deviation of 3.34 dt/acre). By comparison, switchgrass yields on the Loring soil were lower, averaging 7.78 dt/acre (standard deviation of 2.91 dt/acre). Net revenues for the soybean-corn rotation on the Memphis and Loring soils averaged $50/acre and $49/acre, respectively. Thus, a switchgrass price higher than $32.50/dt was needed to induce production on the Loring soil when the objective was to maximize net revenues.

Contracting 50% to 100% of expected production at $32.50/dt did provide some favorable risk-return tradeoffs from diversification into bioenergy crops on the Loring soils. With a 50% contract level at the two highest levels of absolute risk aversion, (0.000003 and 0.000004), 95 and 311 acres out of the 1,200 acres on the Loring soil portion of the farm were converted to switchgrass (Table 3). Increasing to the amount of expected production contracted to100% marginally increased the amount of acreage converted to switchgrass on the Loring soils (Table 4). At the higher price of $35/dt, switchgrass rather than the corn-stover combination provided the most favorable risk-return tradeoffs for risk averse decision makers. Because more tons of biomass were produced with switchgrass than with corn stover, the total amount of biomass supplied to the biomass conversion facility rose.

Offering a higher contract price of $35/dt on 50% of expected production still did not induce biomass production on the Loring acreage when the objective is to maximize net revenues (Table 5). Marginal increases in acreage converted to switchgrass on the Loring soil over the $32.50/dt 100% contracted scenario were observed when absolute risk aversion was varied from 0.000001 to 0.000004. When 100% of expected production was contracted at $35/dt, all of the Loring soil was converted to biomass production under net revenue maximization. Because of the 2,000 hour hired labor constraint, biomass production on the Loring soil was split between switchgrass (175 acres) and the corn-stover combination (1,025 acres). An average of 10,039 dt of biomass was supplied to the conversion facility, a jump of 245% (7,133 dt) over the no forward contract scenario. When the hired labor constraint was relaxed, all of the Loring acres were converted to switchgrass production. The optimal farm plan when risk aversion was considered was to produce 458 acres of switchgrass and 742 acres of the soybean-corn rotation on the Loring soil. Again, if hired labor was not constrained, all of the Loring acres were converted to switchgrass production.

Results indicate that the largest level of biomass production would be provided by the representative farm offering a contract price of $35/dt on 100% of expected production. However, an important factor influencing the ability of the representative farm to provide biomass was labor during the November-December period when biomass was assumed to be harvested. A biomass user facility that provides custom harvest services may be able to induce additional biomass production at a $35/dt contract price, especially on the commonly found Loring soils in west Tennessee.

Conclusions

This study developed a farm-level model to evaluate the ability and willingness of farmers to provide biomass feedstocks for a northwest Tennessee 2400 acre grain farm. A quadratic programming model incorporating farm labor and land quality constraints, biomass yield variability, crop and energy price variability, alternative contractual arrangements, and risk aversion was developed for the analysis. Yields and prices for 1977 through 2001 were used to calculate net revenues for the risk programming model.

The important findings from this research were as follows. First, a market for biomass based on its energy equivalent value as a substitute for gasoline in ethanol production may provide positive risk management benefits for Tennessee grain farmers. Under this scenario using 1977 through 2001 prices, biomass prices averaged $27.45/dt (standard deviation of $6.38/dt) for wheat straw, $28.56/dt (standard deviation of $6.64/dt) for corn stover, and $30.14/dt (standard deviation of $7.01/dt) for switchgrass.

The opportunity to diversify the farm crop enterprise mix through biomass production may improve mean net revenues and reduce the variability of net revenues. Switchgrass production, rather than corn stover production, provided the best risk-return tradeoff in the analysis. Wheat straw production was not a risk efficient alternative for the representative grain farm. Second, a forward contracting mechanism that provides a guaranteed biomass price on a portion of expected production also may also provide positive risk management benefits to farmers and may induce additional biomass production on Tennessee grain farms. A guaranteed price that was $2.50/dt to $5.00/dt above the average energy equivalent value as a substitute for gasoline in ethanol production, doubled and tripled, respectively, the biomass supplied by the representative farm. Contracting 100% of expected production provided the best risk-return tradeoff for farmers. Finally, at the higher contract prices, additional labor resources would be needed by the farm to allow more production of switchgrass. Custom harvesting services provided by the biomass user facility may allow farmers to provide supply more biomass for energy production.

References

Bernow, S., W. Dougherty, and J. Dunbar, 2002. Texas' Global Warming Solution, Tellus Institute, Cambridge, MA, February.

Cundiff, J.S., and L.S. Marsh, 1996. Harvest and storage costs for bales of switchgrass in southeastern U.S., *Bioresource Technology* 56 (1996):95-101.

De La Torre Ugarte, D.G., M.E Walsh, H. Shapouri, and S.P. Slinsky, 2004. The economic impacts of bioenergy crop production on U.S. agriculture. Washington, DC: U.S. Department of Agriculture, Office of Chief Economist, Office of Energy Policy and New Uses, AER 816

DiPardo, J., 2001. Outlook for biomass ethanol production and demand, U.S. Department of Energy, Energy Information Administration, April. www.eia.doe.gov/oiaf/ analysispapers/pdf/biomass.pdf.

Downing, M., D., Langseth, R. Stoffel, and T. Kroll, 1996. Large scale hybrid poplar production economics, 1995 Alexandria, MN--establishment cost and management, Proceedings of Bioenergy '96, Nashville, TN, September 15-19, pp. 467-471.

Duffield, J., and H. Shapouri, 1998. Biodiesel developments: New markets for conventional and genetically modified agricultural products, U.S. Department of Agriculture, Economic Research Service, ERSAER770, September.

Duffy, M., and V.Y. Nanhou, 2001. Costs of producing switchgrass for biomass in southern Iowa, Iowa State University, PM1866, April.

English, B.C., R. Alexander, Loewen, Coady, G. Cole, and R. Goodman, 1992, Development of a farm-firm modeling system for evaluation of herbaceous energy crops, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/SUB/88-SC616/2.

English, B. C., and R.J. Menard, 2002. Conservation efforts and their impacts on rural regions, Final Report, NRCS Cooperative Agreement 68-3A75-3-139, December.

English, B.C., R.J. Menard, and D.G. De La Torre Ugarte, 2004 Using corn stover for ethanol production: A look at the regional economic impacts for selected midwestern states. University of Tennessee, Department of Agricultural Economics, Knoxville, TN. Online athttp://web.utk.edu /~aimag/pubs/cornstover.pdf

Evans, M.K., 1997. The economic impact of the demand for ethanol, Midwestern Governors Conference, February.

Food and Agricultural Research Institute, 2001. Impacts of increased ethanol and biodiesel demand, FAPRI-UMC Report # 13-01, October.

Gerloff, D. Field Crop Budgets for 2005, 2005. AE 05-32. University of Tennessee Extension, Knoxville, TN

Graham, R.L., E. Lichtenberg, V.O. Roningen, Hosein Shapouri, and M.E. Walsh (1995), The economics of biomass production in the United States," *Proceedings of the Second Biomass of the Americas Conference*, Portland, OR, August 21-24.

Haq, Z., 2001. Biomass for electricity generation, U.S. Department of Energy, Energy Information Administration, Online at: http://www.eia.doe.gov/oiaf/ analysispapers/ pdf/biomass.pdf.

Jones, J.W., K.J. Boote, G. Hoogenboom, S. Jagtar, G.G. Wilkerson, 1989. *SOYGRO* V *5.42: Soybean Crop Growth Simulation Model: User's Guide;* Department of Agricultural Engineering and Department of Agronomy, University of Florida Gainesville.

Johnson, L.A., 1991. Guide to farm planning. University of Tennessee Agricultural Extension Service, Knoxville, TN. EC622.

Johnson, R.G. and D.A. Baugsund, 1990. Biomass resource assessment and potential for energy in North Dakota, North Dakota State University, Agricultural Economics Department, July.

Lindsey, C.A. and T.A. Volk, 1998. Economic and business model of a commercial willow crop enterprise, Proceedings of Bioenergy '98: Expanding Bioenergy Partnerships, Madison, WI, October 4-8, pp. 186-198.

McCarl, B.A., D.M. Adams, and R.J, Alig, 2000. Analysis of biomass fueled electrical power plant: implications in the agricultural and forestry sectors, *Annals of Operations Research* 94:37-55.

Musser, W.N., H.P. Mapp, Jr., and P.J. Barry, 1984. Chapter 10: Applications I: Risk programming, pp.129-147. In (P.J. Barry), *Risk Management in Agriculture*. Iowa State University Press, Ames, IA.

Nelson, R.G., M.E. Walsh, and J. Sheehan, 2004. The Supply of Corn Stover in the Midwestern United States, Proceedings of the Agriculture As a Producer and Use of Energy Conference, Farm Foundation, Washington, DC. (in press).

Pelletier, R.C., 2002. The Importance of detrending. CSI Technical Journal, 20(12). Online: http://www.csidata.com/tech/journal/csinews/200212/page01.html.

Raneses, A., R., Lewrene, K. Glaser, and J. M. Price, 1996. Potential niche markets for biodiesel and their effects on agriculture, Proceedings of Bioenergy '96, Nashville, TN, September 15-19, pp. 163-170.

Ritchie, J.T; U. Singh, D. Godwin, and L. Hunt, 1989. *A User's Guide to CERES – Maize V. 2.10;* International Fertilizer Development Center; Muscle Shoals

U.S. Congress Council of Economic Advisors. 2005. Economic report of the president. U.S. Gov. Print. Office, Washington, DC.

U.S. Department of Agriculture, Office of Chief Economist, Office of Energy Policy and New Uses, 2002. Effects on the farm economy of a renewable fuels standard for motor vehicle fuel, August.

U.S. Department of Agriculture, Natural Resource Conservation Service. 2005. Major Land Resource Areas. Avaliable Online at: http://www.nrcs.usda.gov/technical/land/mlra/

U.S. Department of Commerce. 1977-2001 *Climatological Data, Tennessee*. National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, Ashville, NC.

U.S. Department of Energy, 2003. *Annual Energy Outlook 2003 with Projections to 2025.* DOE/EIA-0383(2003). Washington, DC: Energy Information Administration, DOE, January.

U.S. Department of Energy, 2005. Table 1. Energy Price and Expenditure Estimates by Source, 1970-2001, Tennessee. Washington, DC: Energy Information Administration, DOE, January. Online at: http://www.eia.doe.gov/emeu/states/ep_prices/total/footnotes.

Urbanchuk, J.M., 2001. An economic analysis of legislation for a renewable fuels requirement for highway motor fuels, AUS Consultants, November.

Tennessee Department of Agriculture, 1978 through 2002 Issues. *Tennessee Agriculture*. Tennessee Agricultural Statistics Service, Nashville, TN.

Tennessee Department of Agriculture, 2004. 2004 *Tennessee Tillage Systems*. Tennessee Agricultural Statistics Service, Nashville, TN. Online at: http://www.nass.usda. gov/tn/NT070504.pdf

Tiller, K., 2001. TnFARMS West Tennessee large grain farm description. Online at: http://agpolicy.org/tnfarm.html.

Vaughan, D.H., J.S. Cundiff, and D.J. Parrish, 1989. Herbaceous crops on marginal sites─erosion and economics, *Biomass* 20:199-208.

Walsh, M.E., D. de la Torre Ugarte, S. Slinsky, R.L. Graham, and D. Ray, 1998. Estimating energy crop production regions, quantities, and price, In *Proceedings of the BIOENERGY'98 Conference*, Great Lakes Regional Biomass Energy Program, pp. 1302-1311.

Walsh, M.E. and D.A. Becker, 1996. BIOCOST: a model to estimate the cost of producing bioenergy crops, *Proceedings of the Bioenergy '96 Conference*, Nashville, TN, September 15-20.

Wang, M., C. Saricks, and D. Santini, 1999. Effects of fuel use on fuel-cycle energy and greenhouse emissions. Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, Argonne, IL. ANL/ESD-38.

Williams, J.R; Jones, C.A; Kiniry, J.R; and Spaniel, D.A; (1989): ‘The EPIC Growth Model’ *Trans. American Soc. Agric. Eng.* 32 (2) 479-511

Table 1. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming No Forward Contract Pricing with the User Facility

	Risk Aversion Coefficient					
Item	Base[Y]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	-----------------------------------$/Acres-----------------------------------					
Mean	98,562	105,091	102,713	102,713	101,585	94,245
Standard Deviation	234,552	199,409	118,696	118,696	115,422	95,081
Collins Soil Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	528	528	528	528	497	296
Switchgrass	0	0	0	0	31	232
Memphis Soil Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	186	672	672	672	672
Corn-Stover	0	486	0	0	0	0
Loring Soil Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	1,200	1,200	1,200	1,200	1,200	1,200
Labor Usage	-----------------------------------Hours-----------------------------------					
Mar-Apr	60	68	43	43	42	37
May-Jun	372	343	328	328	326	313
Sep-Oct	1,128	1,065	812	812	798	703
Nov-Dec	0	585	1,411	1,411	1,476	1,899
Labor Hired	603	533	1,170	1,170	1,226	1,591

[Z]The bioenergy price received by the farmer was assumed to be based on energy equivalent values to gasoline for production of ethanol using 1977 through 2001 prices.
[Y]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.

Table 2. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming a Forward Contract Price of $30/dt and a Contract Yield Level of 100% of Expected Yield

	Risk Aversion Coefficient					
Item	Base[Z]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	---------------------------------$/Acres----------------------------------					
Mean	98,562	104,273	100,936	100,936	98,387	94,298
Standard Deviation	234,552	204,571	140,749	140,749	134,082	124,872
Collins Soil Crop Acres						
Soybean-Corn Rotation	528	528	528	528	528	528
Switchgrass	0	0	0	0	0	0
Memphis Soil Crop Acres	----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	186	672	672	672	672
Corn-Stover	0	486	0	0	0	0
Loring Soil Crop Acres	----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	1,200	1,200	1,200	1,200	1,113	974
Switchgrass	0	0	0	0	87	226
Labor Usage	----------------------------------Hours-----------------------------------					
March-April	60	68	43	43	41	38
May-Jun	372	343	328	328	323	314
Sep-Oct	1,128	1,065	812	812	771	706
Nov-Dec	0	585	1,411	1,411	1,594	1,887
Labor Hired	603	533	1,170	1,170	1,328	1,580

[Z]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.

Table 3. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming a Forward Contract Price of $32.50/dt and a Contract Yield Level of 50% of Expected Yield

	Risk Aversion Coefficient					
Item	Base[Z]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	---$/Acres---					
Mean	98,562	109,357	109,357	107,590	104,924	103,590
Standard Deviation	234,552	135,251	128,554	120,678	111,092	107,534
Collins Soil Crop Acres	---Acres---					
Soybean-Corn Rotation	528	528	528	528	528	528
Memphis Soil Crop Acres	---Acres---					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	672	672	672	672	672
Loring Soil Crop Acres	---Acres---					
Soybean-Corn Rotation	1,200	1,200	1,200	1,105	961	889
Switchgrass	0	0	0	95	239	311
Labor Usage	---Hours---					
March-April	60	43	43	41	37	35
May-Jun	372	328	328	322	313	308
Sep-Oct	1,128	812	812	767	700	666
Nov-Dec	0	1411	1411	1612	1914	2065
Labor Hired	603	1,170	1,170	1,343	1,604	1,734

[Z]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.

Table 4. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming a Forward Contract Price of $32.50/dt and a Contract Yield Level of 100% of Expected Yield

	Risk Aversion Coefficient					
Item	Base[Z]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	-----------------------------------$/Acres-----------------------------------					
Mean	98,562	116,002	115,257	112,409	111,460	111,172
Standard Deviation	234,552	140,749	134,993	118,114	114,716	113,942
Collins Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	528	528	528	528	528	528
Memphis Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	672	672	672	672	672
Loring Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	1,200	1,200	1,125	840	745	717
Switchgrass	0	0	75	360	455	483
Labor Usage	-----------------------------------Hours-----------------------------------					
March-April	60	43	41	34	32	31
May-Jun	372	328	323	305	299	297
Sep-Oct	1,128	812	777	643	599	585
Nov-Dec	0	1,411	1,568	2,166	2,366	2,380
Labor Hired	603	1,170	1,305	1,822	1,994	2,000

[Z]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.

Table 5. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming a Forward Contract Price of $35/dt and a Contract Yield Level of 50% of Expected Yield

	Risk Aversion Coefficient					
Item	Base[Z]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	-----------------------------------$/Acres-----------------------------------					
Mean	98,562	116,890	115,877	114,049	113,440	113,136
Standard Deviation	234,552	128,554	119,245	107,134	104,738	103,886
Collins Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	528	528	528	528	528	528
Memphis Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	672	672	672	672	672
Loring Soil Crop Acres	-----------------------------------Acres-----------------------------------					
Soybean-Corn Rotation	1,200	1,200	1,086	879	810	776
Switchgrass	0	0	114	321	390	424
Corn-Stover	0	0	0	0	0	0
Labor Usage	-----------------------------------Hours-----------------------------------					
Mar-Apr Labor	60	43	40	35	33	33
May-Jun Labor	372	328	321	307	303	301
Sep-Oct Labor	1,128	812	758	661	629	613
Nov-Dec Labor	0	1,411	1,651	2,085	2,230	2,302
Total Labor Hire	603	1,170	1,378	1,752	1,876	1,939

[Z]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.

Table 6. Risk Efficient Net Revenues, Crop Acreages, and Labor Usage Assuming a Forward Contract Price of $35/dt and a Contract Yield Level of 100% of Expected Yield

	Risk Aversion Coefficient					
Item	Base[Z]	0.000000	0.000001	0.000002	0.000003	0.000004
Net Revenue	--------------------------------$/Acres----------------------------------					
Mean	98,562	136,901	135,346	135,346	135,346	135,346
Standard Deviation	234,552	136,081	114,615	114,615	114,615	114,615
Collins Soil Crop Acres	----------------------------------Acres------------------------------------					
Soybean-Corn Rotation	528	528	528	528	528	528
Memphis Soil Crop Acres	----------------------------------Acres------------------------------------					
Soybean-Corn Rotation	672	0	0	0	0	0
Switchgrass	0	672	672	672	672	672
Loring Soil Crop Acres	----------------------------------Acres------------------------------------					
Soybean-Corn Rotation	1,200	0	742	742	742	742
Switchgrass	0	175	458	458	458	458
Corn-Stover	0	1,025	0	0	0	0
Labor Usage	----------------------------------Hours----------------------------------- -					
Mar-Apr Labor	60	64	32	32	32	32
May-Jun Labor	372	281	299	299	299	299
Sep-Oct Labor	1128	781	597	597	597	597
Nov-Dec Labor	0	2,189	2,373	2,373	2,373	2,373
Total Labor Hire	603	2,000	2,000	2,000	2,000	2,000

[Z]The risk efficient farm plan in the absence of biomass crop alternatives for absolute risk aversion levels ranging from 0 to 0.000004.