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Viability of Cellulosic Feedstock Production from Producer to Biorefinery

Roland J. Fumasi, Steven L. Klose, Greg H. Kaase, James W. Richardson, and Joe L. Outlaw[1]

Introduction

Annual production of ethanol for fuel in the United States has risen from 175 million gallons in 1980 to 6.5 billion gallons in 2007 (Renewable Fuels Association (RFA), 2008). While nearly all of the U.S. ethanol supply is currently derived from corn, concerns about environmental sustainability and potential impacts on the food supply chain have brought corn-based ethanol out of favor with some. Advanced biofuels such as cellulosic ethanol are expected to be the preferable long-term source of renewable energy (Council for Agricultural Science and Technology (CAST), 2007). The recently enacted Energy Independence and Security Act of 2007, mandates that the United States produce 16 billion gallons of cellulosic biofuel by 2022, representing 44% of the total biofuel mandate (Wyant, 2007). The push for cellulosic ethanol has prompted the U.S. Department of Energy (US-DOE) to award millions in cellulosic research grants (US-DOE, 2008). The southeastern United States, from the upper coast of Texas to northern Florida, is viewed by some private sector grant recipients as potentially being the most agronomically favorable geographic region for cellulosic feedstock (biomass) production. However the economics of such production, particularly for newer varieties of sorghum and sugarcane, have yet to be fully explored. Tembo, Epplin, and Huhnke (2003) and Mapemba *et al*. (2007) have studied similar economic issues pertaining to perennial grasses in the southern Great Plains.

The specific type of technology employed will potentially impact the type of biomass that the biorefinery must use as its primary input. The type of biomass used must be both environmentally and economically sustainable within the geographic area chosen for the biorefinery. Crop density (acres planted per square mile) and energy yield are two vital components in biomass choice (De La Torre Ugarte *et al.*, 2003 and English *et al.*, 2006). The crop chosen must have adequate energy yield per acre (gallons of ethanol that can be produced), which is a function of the crop yield. Sufficient crop density of the chosen feedstock is also required so that transportation costs can be minimized, as it is estimated that the cost of harvesting and transporting biomass can comprise up to 75% of the total cost of biomass production (CAST, 2007; Epplin *et al.*, 2007; and Mapemba *et al.*, 2007). Discussions with university agronomists have revealed two potential feedstocks, sugarcane and hybrid sorghum, which may be most suitable for cellulosic ethanol production (Rooney, 2007). Varieties of each crop have been developed to maximize biomass yield per acre.

Farmers in the Upper Coast region of Texas have begun to ask whether the geographic, agronomic, and economic conditions present in the area make them suitable candidates to produce cellulosic feedstock, and if so, what types of specific energy crops should be pursued. Cursory examination of the area suggests that both hybrid sorghums and sugarcane should grow well. Growers in the area have the technical expertise to grow energy crops, and rainfall is abundant. The availability of abundant and suitable farmland, which is close to potential refinery building sites, and the fact that relatively few economically viable crop options are available to growers, suggest that this area may be a wise choice for locating a biorefinery.

Economic Problem

What is the cost and viability of obtaining cellulosic feedstocks in the Upper Coast region of Texas, and what is the potential on-farm financial impact of dedicating acreage to energy feedstock production in that region?

Hypothesis

The financial impact on the farm (and therefore the viability of obtaining a critical mass of feedstock) will depend on the specific set of dedicated energy crops grown, the alterna-

[1] Fumasi is a Research Associate; Klose is an Associate Professor and Extension Economist; Kaase is an Extension Program Specialist III; Richardson is a Regents Professor and Senior TAES Faculty Fellow; and Outlaw is a Professor and Extension Economist, all respectively, in the Department of Agricultural Economics at Texas A&M University, College Station, Texas.

tive crop mixes available to the farm, and the profit potential of the biorefinery at the necessary feedstock contract prices.

Research Outline

1) Estimate the most cost effective and agronomically feasible dedicated energy crop mix for cellulosic ethanol production in Southeast Texas,

2) Estimate the contract price per ton needed for farmers to grow cellulosic feedstock and forgo their next best alternative in Southeast Texas,

3) Determine the financial impact on the whole farm of switching from its current crop mix to one consisting of dedicated energy crops, and

4) Estimate the cost per ton to harvest and transport alternative cellulosic crops to a biorefinery located in Southeast Texas.

Methodology

Module 1: Estimation of Minimum Contract Prices, Delivered Price, and Least-Cost Energy Crop Mix

Agronomists, local producers, and ethanol industry representatives were consulted to determine the most potentially feasible types of cellulosic ethanol crops for the growing region (Rooney, 2007 and Farm Panel, 2007). Feedstocks most attractive for this process are those that yield a high amount of cellulosic material per acre, including sugarcane and high biomass hybrids of sorghum. The most suitable sources of biomass were identified as hybrid sorghum hay (HS Hay), hybrid sorghum green chop (HS GC), high-biomass sorghum green chop (HB), and billeted, sugarcane (Cane).[2] The farm panel also identified rice and pasture hay as the most viable alternatives to growing dedicated energy crops in the geographic area.

A two-stage contract structure was assumed. The growing contracts included a stage-1 payment per acre equal to the expected variable production costs. The per production unit stage-2 payment was set equal to the price needed to cover 150% of fixed costs per acre based on expected yields. This structure gives the producer incentive to meet or exceed yield expectations. While both the biorefinery and the producer share downside yield risk, the biorefinery is faced with the risk of dealing with excess biomass production. Two-stage contract structures have been proposed in recent biomass production research (Clark, English, and Garland, 2007; Epplin *et al.*, 2007).

Price, yield, and cost data for existing non-energy crop alternatives were provided by local producers. Estimates of energy crop yields and costs of production were reached using a combination of information from the panel farmers, representatives from the cellulosic ethanol industry, and Agricultural Extension agronomists. The agronomists also estimated the potential harvest periods in the geographic region for the alternative energy crops. The harvest periods were used to constrain the analysis to only those energy crop mixes that could feasibly supply year-round feedstock to the biorefinery. The least-cost crop mix to the biorefinery was then identified.

FAPRI (2007) baseline estimates for U.S. crop prices and inflation rates were localized and used in conjunction with our panel data to estimate alternative crop budgets through 2017 (Farm Panel, 2007). Using the proposed contract structure and the estimated enterprise budgets, grower contract prices were estimated for each energy crop in each year. Once the contract prices were fixed, yield, input cost, and price (for non-energy crops) risk was introduced into the budgets using Monte Carlo simulation to draw from a combination of empirical and GRKS distributions (Richardson, Klose, and Gray, 2000). The method produced probabilistic forecasts of net returns per acre for 2008-2017, for both energy crops and non-energy alternatives. Stochastic efficiency analysis was performed on the simulated outcomes of net returns to determine if growers would indeed have an adequate incentive to produce dedicated energy crops.

Based on interviews with ethanol industry representatives, it was assumed that the biorefinery would be responsible for the harvesting and transportation of biomass (Farm Panel, 2007). Harvest costs per unit of feedstock were based on the 2004 Texas Custom Rates Statistics publication (NASS, 2004) and then adjusted using FAPRI baseline inflation estimates through 2017 (FAPRI, 2007). Transportation costs per unit of feedstock were modeled as a function of the average distance hauled and the variable transportation cost per mile. Contracted acres needed was modeled as a function of the dry matter tons of each feedstock needed, the expected dry matter yields per acre, and the expected bio-density of each crop per square mile. Feedstock needs were based on a conversion rate of 90 gallons per ton of dry matter (De La Torre Ugarte *et al.*, 2003; English *et al.*, 2006; Richardson *et al.*, 2006; Epplin *et al.*, 2007; and Mapemba *et al.*, 2007). Once total planted acres needed were estimated, average hauling distances were calculated using work done by French, which accounts for a square road system (1960). Variable transportation costs per mile were based on the 2004 Texas Custom Rates Statistics publication (NASS, 2004) and were adjusted using FAPRI baseline inflation estimates through 2017. Total delivered

[2] Each of the three sorghums evaluated is a distinct hybrid. While we have chosen to call one of the sorghum varieties "high biomass", all three varieties are designed to maximize biomass yield per acre. The HB crop is allowed to mature more thoroughly than the green chop or hay varieties, and is cut only once per season. The HB crop becomes more "woody" like cane and is therefore less resistant to lodging during harsh weather conditions than typical sorghum crops. However, the stalk diameter of HB sorghum is still considerably less than cane, so harvesting cost for the HB crop is lower. The HB type of crop is harvested similarly to typical green chop, but is assumed to be cut at 40% dry matter as opposed to green chop at 30%.

costs per ton of dry matter to the biorefinery for each feedstock were estimated by summing the contract price to grow, the harvest cost, and the transportation cost, all on a ton dry matter basis.

Monte Carlo estimates of the average cost of feedstock per delivered dry ton were produced under alternative energy crop mixes, and included consideration of harvest periods for each energy crop and differing yield risks depending on the type of crop. The least-cost energy crop mix (based on delivered cost) was identified. Table 1 gives a summary of the exogenous variables and assumptions used in this analysis, including the information received from the farm panel and the agronomists. Note that grass hay is assumed to be previously established. Planting costs for the annual crops are accounted for under growing costs. Therefore, only the perennial cane crop has separate establishment costs.

Module 2: Financial Impacts on the Farm

The Financial and Risk Management Assistance program (FARM Assistance) consists of a state-of-the-art computerized decision-support system and extension risk management specialist working one-to-one with producers to provide individualized economic and risk assessment evaluations. Alternative management plans and new technologies can be analyzed relative to their risk impacts on the financial condition of the operation over a ten-year planning horizon (Klose and Outlaw, 2005).

While Module 1 identifies potential biomass pricing and costs of production, Module 2 analyzed the farm level impacts to a producer's overall financial performance and risk exposure. In this module a 10-year simulation of financial performance and position using stochastic commodity prices and yields was used to simulate farm level performance for the 2007-2016 period. Utilizing the FARM Assistance approach, a model farm was developed to represent actual producers in the production region. A baseline scenario of the model farm provides the current financial outlook for a 3,000 acre farm producing rice and hay (Farm Panel, 2007). The energy crop scenarios include shifting half of the available acreage to the production of 1) hybrid sorghums and 2) sugarcane, while the farm continues rice and hay production on the remaining acreage.

Results

Most Cost Effective and Agronomically Feasible Energy Crop Mix for Biorefinery

Due to differences and overlaps in potential harvest periods, the four most agronomically feasible energy crop mixes were found to be 1) hybrid sorghum green chop (HS GC) four months, hybrid sorghum hay (HS hay) two months, sugarcane (cane) six months, 2) HS GC two months, HS hay two months, hybrid sorghum high biomass (HS HB) two months, cane six months, 3) HS GC two months, HS hay eight months, HS HB two months, and 4) HS GC four months, and HS hay eight months. Average delivered price was estimated for the four scenarios, and the least cost alternative was found to be HS GC two months, HS hay two months, HS HB two months, and cane six months. Cane and HS hay were the most costly crops (HS hay being most expensive), but while the use of HS hay could be minimized, the October through March harvest period for cane made it the only viable crop during that part of the year. Subsequent results reported in this paper pertain to the least cost alternative crop mix only.

Estimated Contract Prices to Grow Feedstocks (2008-2017)

The estimated contract price to grow sugarcane was found to be lower than the sorghum alternatives by approximately $9 per dry ton in each year. Cane averaged $29 per dry ton while HS hay, HS GC, and HS HB averaged $38, $38, and $40 per dry ton respectively. In the case of cane, lower annual input costs made up for its high establishment cost, which was spread over a six year life of the crop. Slightly lower input costs for HS hay and HS GC made these crops less costly to produce than the HS HB. Contract prices for all four crops rose steadily over the 10-year planning horizon, tracking the general inflationary trend. Table 2 contains the complete set of contract prices, including the base year, 2007.

Estimated Returns to Growers (2008-2017)

The 10-year average of annual net returns per acre was highest for cane ($68) versus the hybrid sorghum crops at $50 for HS GC, $57 for HS hay, and $55 for HS HB. Both rice and pasture hay were expected to yield net economic losses averaging -$133 and -$158 per acre respectively. While rice had the highest potential annual returns ($600/acre) it also had the highest potential loss (-$700). Cane exhibited the least variability in net returns due it having the least yield risk. Under the proposed contract structure, producers are expected to have less than a 5% chance of losing money growing cane, a 20% chance growing the hybrid sorghums, 70% growing rice, and 80% growing pasture hay. Table 3 shows descriptive statistics for net returns in 2012, which was found to be representative of each of the ten years simulated.

Stochastic Efficiency with Respect to a Function (SERF) analysis was applied to the simulated net returns to rank the crop choices while accounting for risk over a relevant range of risk attitudes (Figure 1). The results indicate that estimated contract prices are adequate to rank all energy crops above the non-energy alternatives over the entire range of attitudes toward risk. A complete explanation of the SERF method can be found in Hardaker *et al.*, 2004.

Whole-Farm Financial Implications (2007-2016)

The model farm used to analyze the farm level impacts of producing the specified energy crops represents a 3,000

Table 1. Exogenous Variables and Assumptions

Baseline Assumptions Year	2007					
Annual Biorefinery Output in Gallons	25,000,000					
Gallons Ethanol Per Ton Dry Matter	90					
Percent of Land Farmable in the Area	90%					
Percent of Farmland Converted	30%					
Operating Loan Rate	8.5%					
Fraction of Year for Growing Portion of Operating Loan	0.5000					
Fraction of Year for Harvesting Portion of Operating Loan	0.1667					
Intermediate Term Loan Rate	8.5%					
Crop	Rice	Grass Hay	HS Hay	HS GC	HB	Cane
Crop Yield/Acre (Wet Ton) (Cwt for Rice)	75.00	9.00	17.65	50	37.5	45
Percent Dry Matter (Decimal Form)			0.85	0.3	0.4	0.34
Crop Rotation (Years)			3	3	3	0
Fixed Hauling Cost Per Acre	0	0	0	0	0	0
Hauling Cost Per Wet Ton (up to 1 mile) (Cwt for Rice)	1.50	16.67	16.67	3.35	3.35	3.35
Variable Hauling Cost Per Wet Ton Per Mile (over 1 mile)	0	1.09	1.09	0.3	0.3	0.3
Fixed Portion of Harvesting Cost Per Acre	55	27	0	0	0	144
Variable Harvest Cost Per Wet Ton	0	36.67	36.67	6.47	6.47	10
Other Revenue Per Acre	0	0	0	0	0	0
Establishment Costs ($ Per Acre)						
Planting						660
Herbicides						47
Number of Years to Spread Establishment Cost						6
Variable Growing Cost ($ Per Acre)						
Seed/Tech	75	0	100	100	100	0
Chemicals	95	10	47	47	47	0
Fertilizer	120	123	120	120	120	27.5
Labor	40	12	20	20	20	12
Fuel	33	8	20	20	20	8
Repair & Maintenance	33	3	15	15	15	3
Other/Custom/Irrigation	80	0	0	0	0	0
Direct Fixed Growing Expenses Per Acre	80	80	80	80	80	80
Cash Rent	50	25	50	50	50	50
Months that Crop Supplies Biorefinery			April & Sept	May - June	July - August	Oct - March
Yield Parameters (Wet Ton) (Cwt for Rice)						
Min	50	6	10	26	20	30
Mid	75	9	17.65	50	37.5	45
Max	85	12	24	66	50	60
Percent of Crop Recovered if Weather Disaster	0.3	0.5	0.5	0.3	0.5	0.75

Table 1 (Cont). Exogenous Variables and Assumptions

Probability of Disaster	0.1									
FAPRI U.S. Baseline Estimates										
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Rice Price ($/cwt)	10.52	10.60	11.03	10.99	11.23	11.26	11.07	11.06	11.30	11.40
All Hay Price ($/ton)	113.96	111.60	111.85	113.09	114.63	115.80	116.73	116.24	115.60	114.84
FAPRI Projected Inflation Rates					Percent Change					
Agricultural Chemicals	1.46	1.08	1.20	1.44	1.23	1.40	1.55	1.56	1.48	1.48
Seed	3.91	3.62	2.38	1.83	1.66	1.58	2.15	2.33	2.21	2.26
Nitrogen Fertilizer	5.78	8.44	1.94	-1.34	-1.17	-1.31	0.75	1.46	1.01	1.54
Wage Rates	4.82	4.00	2.60	2.24	1.58	1.56	2.24	2.24	2.08	2.18
Petroleum Fuel, Oils	2.87	1.60	1.40	-0.46	-0.97	-0.76	0.31	0.72	0.28	0.60
Repairs	5.27	5.19	3.09	2.15	1.84	1.66	2.18	2.33	2.18	2.22
Interest	4.92	5.13	5.24	5.30	5.33	1.52	1.71	1.81	0.73	0.73
Farm Services	4.29	3.71	2.47	1.99	1.79	1.65	2.18	2.33	2.20	2.22
Rent	4.27	2.21	1.31	0.91	0.32	0.24	0.23	0.16	0.18	0.18
Direct Fixed	-4.53	-3.17	-3.04	-2.56	-2.05	1.19	1.34	1.38	1.38	1.38
Beaumont Area Price Wedges										
Rice	0									
Hay	-35									

Table 2. Estimated Contract Prices Based on Expected Yields ($/Ton Dry Matter), 2008-2017

Year	HS GC	HS Hay	HS HB	Cane
2008	36.24	36.23	38.45	27.51
2009	37.35	37.34	39.75	28.19
2010	37.75	37.75	40.21	28.59
2011	37.80	37.79	40.22	28.91
2012	37.83	37.82	40.24	29.18
2013	38.03	38.02	40.41	29.53
2014	38.53	38.53	40.93	30.04
2015	39.13	39.13	41.56	30.60
2016	39.66	39.66	42.12	31.07
2017	40.26	40.26	42.76	31.59

Table 3. Descriptive Statistics for Simulated Net Returns in 2012 ($/Acre)

Statistical Measure	Rice	Pasture Hay	HS GC	HS Hay	HS HB	Cane
Mean	-88.70	-113.21	49.18	55.39	53.78	66.99
StDev	245.04	125.95	70.30	65.18	73.97	34.11
CV	-276.27	-111.25	142.96	117.67	137.54	50.92
Min	-705.54	-435.86	-210.54	-174.38	-200.84	-32.70
Max	587.70	248.36	213.11	224.00	233.41	193.61

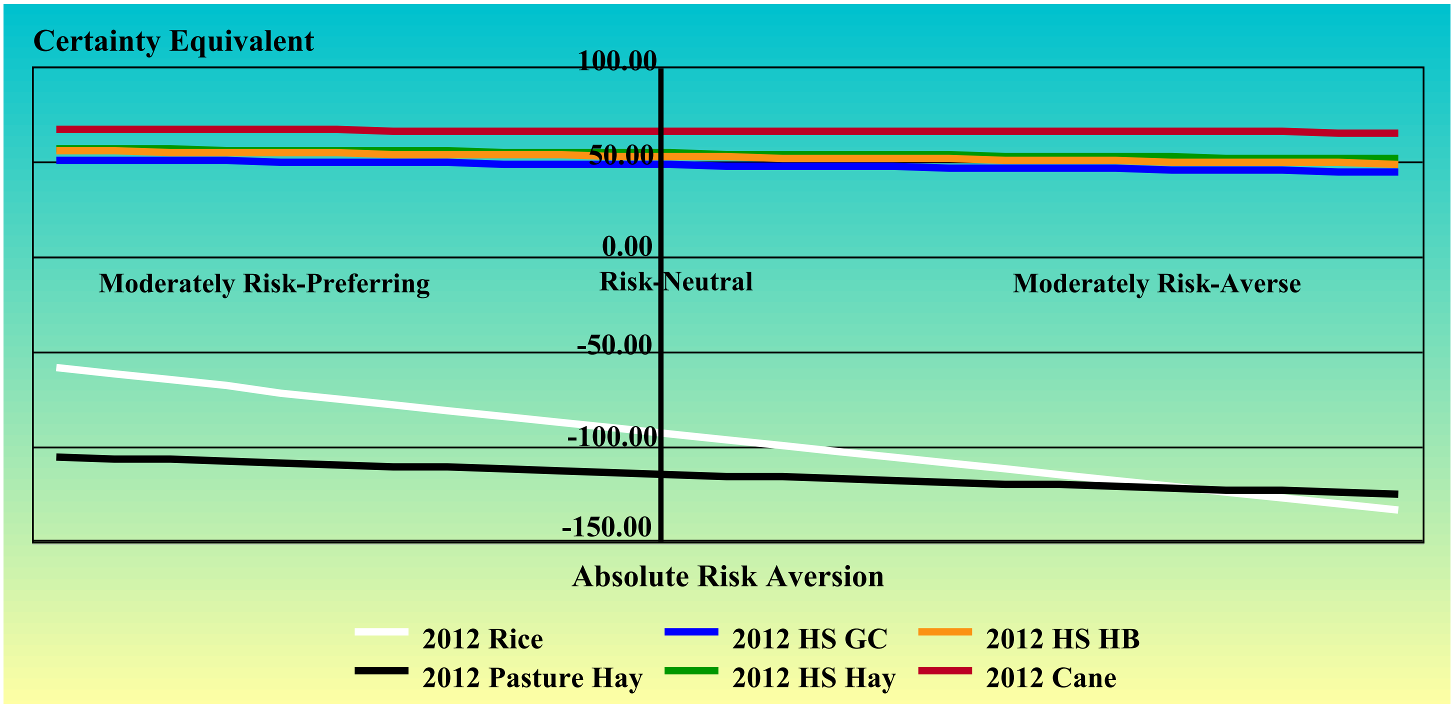

Figure 1. Stochastic Efficiency with Respect to A Function (SERF) under a Negative Exponential Utility Function for Net Returns Per Acre in 2012

acre rice and hay farm in the upper coast region of Texas in the area of Beaumont. On half of the land (1,500 acres), the farm produces rice on a three year rotation, planting 500 acres and idling 1,000 acres. Coastal hay is produced on the remaining 1,500 acres. It is assumed that most of the land was historically in crop production, and therefore the farm continues to carry 1,500 base acres (1,000 acres of rice base, 400 acres of corn base, and 100 acres of sorghum base). The sole proprietor is assumed to own half of the acres and cash lease the remaining half. Assumptions of cost of production and contract prices match those used for the broader analysis in this research. The Baseline scenario indicates a viable operation, on average generating positive net farm income and cash flow, as well as real net worth growth.

Rice and Hay Baseline

Table 4 provides the key indicators for the baseline and alternative financial projections. The farm generates approximately $1.5 million in annual receipts with a 0.81 average expense-to-receipts ratio. Following a profitable year in 2007, the farm settles into a steady pattern of an annual average net cash farm income (NCFI) of about $200,000. In each year NCFI can range from negative $150,000 to a high of $600,000. The analysis suggests a 50% probability of NCFI falling between zero and $350,000.

The ten-year outlook suggests an average cash flow growth, indicating the level of profit is sufficient to cover non-farm expense requirements such as family living costs, taxes, and capital purchases. On average, the cash balance grows to $236,000 by the year 2016 (Figure 2). Figure 2 also provides a picture of the cash flow risk as measured by the probability of the farm experiencing a negative cash position in any given year. While the farm has a stable average cash outlook, it carries about a 30% chance of not achieving a positive cash flow in each year of the projection.

A healthy profit level and cash position allow the farm to project positive growth in real net worth (RNW) as well. On average, real net worth grows from $2.6 million to just over $3.5 million (Table 4). The range of possibilities for ending real net worth start with a low of about $2.7 million suggesting a slight chance of no equity growth relative to the 2007 starting equity. On the other hand, the farm could experience equity growth bringing RNW to as much as $4.5 million by 2016.

Rice, Hay, and Hybrid Sorghum

For the hybrid sorghum scenario, it is assumed that half of the productive land is dedicated to growing hybrid sorghum. The crop mix consists of 750 acres of hay, 750 (250 planted annually) acres of rice land, and 1,500 acres devoted to hybrid sorghum. Production constraints prevent the producer from planting hybrid sorghum continuously. Similar to rice in the area, agronomists suggest a three year rotation. Of the 1,500 acres devoted to hybrid sorghum, the farm annually produces 1,000 acres of sorghum for grain and 500 acres of biomass sorghum (approximately 167 acres each of hybrid

Table 4. Selected Estimated Variables in the Base Scenario and the Energy Alternatives, 2007-2016

Year	Base	Hybrid Sorghums	Sugarcane		Base	Hybrid Sorghums	Sugarcane
	Crop Receipts ($1000)				Net Cash Farm Income ($1000)		
2007	1,507.33	1,304.97	1,144.89	2007	349.75	336.89	-649.20
2008	1,387.75	1,273.04	1,293.47	2008	212.47	291.19	527.18
2009	1,373.58	1,266.88	1,302.38	2009	195.57	285.81	568.40
2010	1,365.19	1,264.91	1,247.07	2010	193.68	288.73	541.45
2011	1,377.83	1,272.40	1,203.62	2011	200.57	291.61	506.92
2012	1,385.37	1,275.14	1,118.72	2012	214.84	296.45	433.47
2013	1,407.49	1,291.22	703.74	2013	230.64	309.12	106.51
2014	1,394.69	1,289.85	1,133.25	2014	218.04	305.97	-797.53
2015	1,391.89	1,288.39	1,363.43	2015	210.06	298.64	607.31
2016	1,381.77	1,286.01	1,376.20	2016	191.72	291.06	650.75
Average	1,397.29	1,281.28	1,188.68	Average	221.73	299.55	249.53
	Government Payments ($1000)				Ending Cash Reserves ($1000)		
2007	94.58	89.03	89.03	2007	141.60	135.64	-754.13
2008	104.97	97.95	97.95	2008	174.92	224.62	-341.50
2009	106.68	99.69	99.69	2009	183.61	297.21	-21.71
2010	105.24	98.63	96.63	2010	186.91	362.46	210.98
2011	97.87	93.79	93.79	2011	178.84	412.00	398.75
2012	96.73	92.24	92.24	2012	196.23	486.06	554.87
2013	96.53	92.15	92.15	2013	225.91	568.03	493.54
2014	97.41	92.70	92.70	2014	240.47	642.60	-435.97
2015	102.40	95.72	95.72	2015	239.56	703.72	20.48
2016	98.06	93.84	93.84	2016	236.06	770.20	389.14
Average	100.05	94.57	94.57	Average	200.41	460.25	51.44
	Disaster & Indemnities ($1,000)				Real Net Worth ($1000)		
2007	4.59	2.29	2.29	2007	2,700.82	2,694.98	1,823.51
2008	7.88	3.94	3.94	2008	2,954.83	3,002.85	2,455.92
2009	6.66	3.33	3.33	2009	3,062.23	3,169.88	2,867.68
2010	10.01	5.01	5.01	2010	3,155.00	3,318.25	3,177.38
2011	10.44	5.22	5.22	2011	3,240.79	3,453.19	3,441.12
2012	12.08	6.04	6.04	2012	3,324.18	3,582.37	3,643.67
2013	8.99	4.49	4.49	2013	3,413.75	3,711.42	3,646.61
2014	8.90	4.45	4.45	2014	3,484.81	3,826.61	2,909.84
2015	15.72	7.86	7.86	2015	3,536.30	3,921.73	3,354.38
2016	11.91	5.95	5.95	2016	3,573.24	4,006.47	3,697.39
Average	9.72	4.86	4.86	Average	3,244.59	3,468.77	3,101.75
	Total Cash Receipts ($1000)				Debt to Asset Ratio (%)		
2007	1,606.50	1,393.30	1,236.22	2007	27.19	27.10	48.44
2008	1,500.61	1,374.92	1,395.36	2008	25.56	24.91	34.61
2009	1,486.93	1,369.91	1,405.40	2009	24.43	23.29	26.66
2010	1,480.45	1,368.55	1,350.71	2010	24.21	22.55	23.40
2011	1,486.14	1,371.41	1,302.62	2011	23.84	21.86	21.46

Table 4 (Cont.). Selected Estimated Variables in the Base Scenario and the Energy Alternatives, 2007-2016

Year	Base	Hybrid Sorghums	Sugarcane		Base	Hybrid Sorghums	Sugarcane
	Total Cash Receipts ($1000)				Debt to Asset Ratio (%)		
2012	1,494.17	1,373.42	1,216.99	2012	23.03	20.69	19.86
2013	1,513.01	1,387.87	800.39	2013	22.47	19.91	19.75
2014	1,501.01	1,387.00	1,230.41	2014	22.44	19.48	30.57
2015	1,510.01	1,391.97	1,467.01	2015	21.81	18.46	23.27
2016	1,493.73	1,385.80	1,475.99	2016	21.18	17.45	19.10
Average	1,507.06	1,380.71	1,288.11	Average	23.62	21.57	26.71
	Crop Expenses ($1000)				Average Annual Operating Expense/Receipts		
2007	1,066.42	877.12	1,669.46	2007	0.75	0.71	1.45
2008	1,095.21	899.42	625.45	2008	0.80	0.73	0.51
2009	1,098.34	903.03	627.70	2009	0.82	0.74	0.51
2010	1,095.41	903.79	626.97	2010	0.82	0.74	0.53
2011	1,092.07	905.00	626.35	2011	0.81	0.74	0.55
2012	1,084.17	903.00	623.22	2012	0.80	0.74	0.59
2013	1,088.05	908.46	544.02	2013	0.80	0.74	0.81
2014	1,088.80	913.06	1,816.60	2014	0.81	0.75	1.58
2015	1,102.19	924.74	636.21	2015	0.81	0.75	0.50
2016	1,103.65	930.60	638.41	2016	0.82	0.75	0.50
Average	1,091.43	906.82	843.44	Average	0.81	0.74	0.76

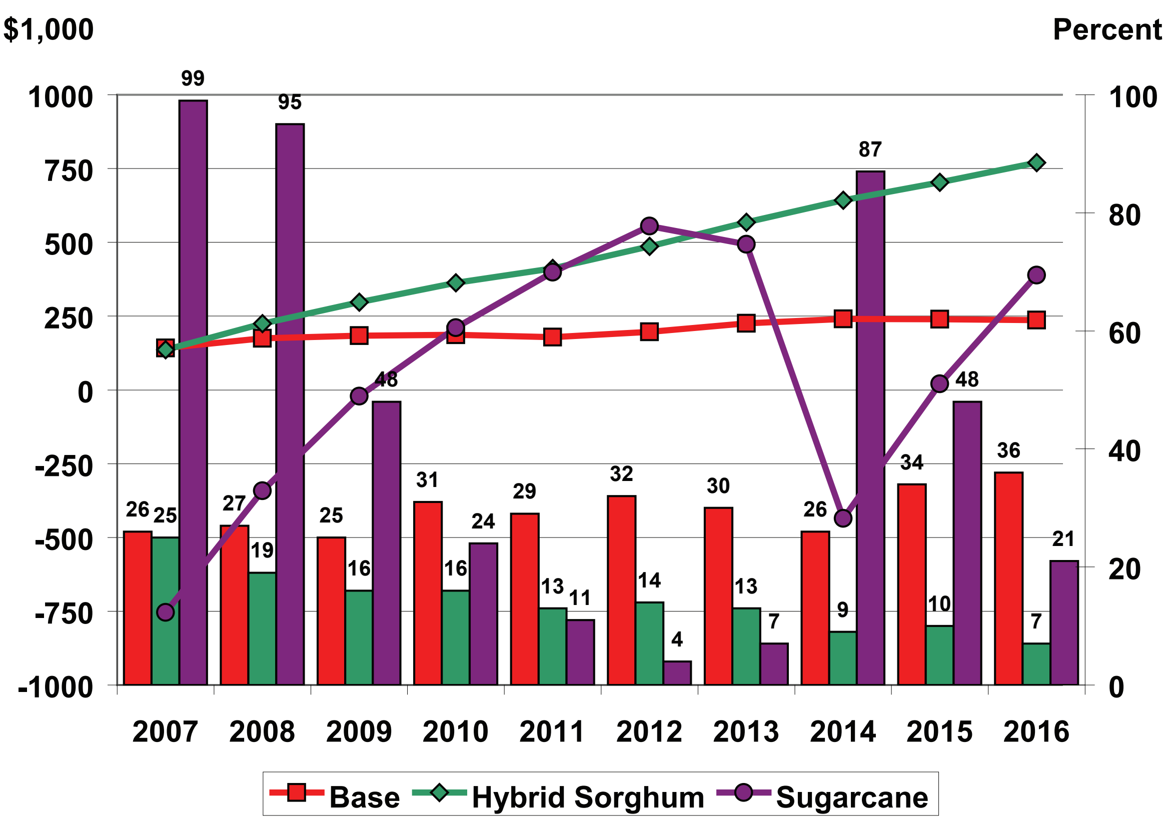

Figure 2. Ending Cash Reserves and Probability of Having to Refinance Operating Note for the Base, Hybrid Sorghum, and Sugarcane Scenarios.

sorghum hay, hybrid sorghum green chop, and hybrid sorghum high biomass).

The general financial outlook for the operation is improved under the hybrid sorghum scenario relative to the baseline. The dictated contract prices and assumed cost of production for the hybrid sorghum improve the efficiency of the operation, as evidenced by a 0.74 expense-to-receipts ratio compared to 0.81 for the baseline (Table 4). Both receipts and expenses are reduced, but the improved efficiency generates a higher average NCFI. NCFI over the ten-year period averages $300,000, an improvement of $80,000 annually over only producing rice and hay. The increased profitability generates even greater growth in cash position over time. Figure 2 shows the final cash position in 2016 grows to just over $750,000, while the probability of negative cash balances is also steadily improved to below 10% by 2016. Growth in real net worth is also indicative of the improved profitability, growing to an average of $4.0 million compared to $3.5 million for the baseline (Table 4).

Rice, Hay, and Sugarcane

Similar to the first alternative, the sugarcane scenario assumes half of the land is switched to sugarcane production. The crop mix consists of 750 acres of hay, 750 (250 planted annually) acres of rice land, and 1,500 acres devoted to sugarcane. Overall the farm's financial performance and position are improved with the addition of sugarcane production. The average NCFI improves from $220,000 in the baseline to approximately $250,000 annually for the sugarcane scenario (Table 4). However, sugarcane, being a perennial crop with a definitive life-cycle, adds an important consideration for the producer. The sugarcane crop is established in the first year of the analysis, produces the highest yields in years 2-4, and then yields taper-off in the 5^{th} and 6^{th} years of the crop.

The sugarcane crop cycle is evident in the outlook for NCFI (Table 4), where 2007 reflects the initial cost of establishing 1,500 acres of sugarcane. Minimal cost of production and stable yields are evident from 2008 through 2012 where NCFI averages in the range of $550,000 annually. Production and price risk (for non-energy crops) create a range of NCFI from $300,000 to $800,000 over the same 5 year period. In 2013 the sugarcane land is idle, and 2014 reflects the establishment cost for the next sugarcane crop. The nature of the sugarcane production is most critical to the farm's cash flow position. Figure 2 illustrates the high probability of negative cash positions associated with the crop establishment years, as well as the years needed to recover to a healthy cash level. Even with a year of no sugarcane production, the farm appears to be on a cash flow trend that is slightly improved over the baseline, but requires more management effort. Table 4 provides projections of RNW under sugarcane production, which is slightly improved on average. The financial outlook for sugarcane ignores any financing and accounting adjustments that could smooth the financial measures over time. All cash expenses are paid in the year incurred, profits assume cash accounting, cash shortages are financed for a 1 year term, and the established sugarcane is never considered an asset. In reality, a manager could finance the cost of sugarcane establishment over several years, capitalize the investment in establishing the crop, and depreciate the expense over the life of the crop. Another option would be to stagger the establishment of sugarcane acreage so that not all of the acreage is idle or established in a single year.

The long-term commitment required for producing sugarcane presents another dynamic for the producer-biorefiner relationship. The analysis of both hybrid sorghum and sugarcane production assumes the contract would be available and in place for the ten-year planning horizon. Hybrid sorghum contracts could possibly exist with shorter duration, while a producer would likely require a longer term commitment from the biorefinery to invest and commit to sugarcane production.

Delivered Cost to Biorefinery Including Growing, Harvesting, and Transportation (2008-2017)

Table 5 presents the range of variability in the biorefinery's growing costs per dry ton. While the expected contract prices per unit are fixed, the first portion of the contact is a lump-sum per acre based on expected variable production costs. The second, per unit, portion is paid on actual production. Therefore the actual, total price paid per unit is a random variable, because of variations in yield. The growing costs shown in Table 5 represent a simulation of the weighted average growing cost over the four energy crops based on the minimum cost crop mix. The average price paid ranges between $34 and $38 per dry ton, including prices that range between $25 and $57 in year 2008, to a range of $28 to $71 by 2017. The absolute minimum price is $25 in 2008, and the maximum is $85 in 2015.

As Table 5 indicates, the harvest and transportation costs per dry ton for the crop mix tend to be approximately $51. The absolute minimum is $41 in 2013, the maximum is $68 in 2017. The average total delivered price per dry ton averages approximately $87 over the ten year projection period. The simulated outcomes of total delivered cost range between a minimum of $69 in 2013, to a maximum of $141 in 2015 (Table 5).

Table 5. Descriptive Statistics for Simulated Key Output Variables for Biorefinery, 2008-2016					
Year	Mean	StDev	CV	Min	Max
Key Output Variable: Growing Cost to Biorefinery 2008-2017					
			($/Dry Ton)		
2008	33.73	5.02	14.89	25.40	57.40
2009	34.74	5.36	15.44	26.04	72.80
2010	35.17	5.37	15.27	26.40	63.16
2011	35.42	5.78	16.31	26.38	65.15
2012	35.55	5.63	15.84	26.20	70.23
2013	35.85	5.77	16.09	26.67	73.77
2014	36.40	5.92	16.25	27.06	63.39
2015	37.06	6.30	16.99	27.40	84.94
2015	37.50	5.68	15.15	26.98	61.16
2017	38.19	6.42	16.82	28.20	70.53
Ket Output Variable: Harvest & Transportation Cost 2008-2017					
			($/Dry Ton)		
2008	49.71	3.02	6.08	43.82	60.28
2009	50.55	3.48	6.88	42.96	61.56
2010	51.29	3.88	7.56	42.34	63.55
2011	51.10	3.89	7.62	42.21	66.69
2012	50.62	3.85	7.60	41.51	65.70
2013	50.26	4.01	7.97	40.95	64.21
2014	50.42	3.94	7.81	41.48	64.87
2015	50.81	4.16	8.18	41.62	64.51
2015	50.93	4.06	7.96	41.45	67.27
2017	51.27	4.24	8.27	41.28	67.50
Ket Output Variable: Total Delivered Cost 2008-2017					
			($/Dry Ton)		
2008	83.44	6.89	8.26	71.07	116.45
2009	85.28	7.40	8.67	70.72	131.91
2010	86.46	7.66	8.86	71.20	120.69
2011	86.52	8.07	9.33	71.69	127.00
2012	86.17	7.81	9.06	70.78	132.30
2013	86.11	8.21	9.54	68.70	134.58
2014	86.83	8.14	9.37	69.92	124.37
2015	87.87	8.78	10.00	71.36	140.85
2015	88.43	7.87	8.90	71.60	124.45
2017	89.46	8.88	9.92	71.29	133.91

Summary and Conclusions

Recent changes to U.S. energy policy indicate that the United States is committed to the successful, commercial introduction of cellulosic biofuels (Wyant, 2007). The economics of delivering biomass to biorefineries is the central theme of this paper. A Monte Carlo simulation and farm panel data was used to estimate the expected potential returns to agricultural producers when growing dedicated energy crops--hybrid sorghum hay, hybrid sorghum green chop, hybrid sorghum high biomass, and sugarcane. A whole-farm simulation model was then used to estimate the overall financial impacts on a model farm that begins to dedicate acreage to energy crop production. Estimates of the harvest and transportation costs of getting biomass from the farm to the biorefinery were also made.

If contract prices assumed in this analysis are viable, dedicated energy crops can be an economic option for agricultural producers in the Upper Coast region of Texas. Cane appears to be the most favorable crop in the more general modeling framework, but when evaluated on a net income, cash flow, and net equity basis for a representative farm the hybrid sorghums may be as favorable. Cane is more resistant to the potentially harsh weather conditions and therefore has less yield variability than the sorghum crops. Cane is also less sensitive to changes in annual input costs. However, planting cane does require a relatively large capital commitment for establishment and gives the producer less planting flexibility than the direct seeded sorghum crops. Farmers should note that contract prices based on expected outcomes can result in actual outcomes that are far less favorable, because of yield risk.

Harvesting and transportation costs account for at least 50% and in some cases 75% of the total delivered cost to the biorefinery. The contract structure proposed ensures that both the grower and the biorefinery share downside yield risk. However, the contracting scenario places additional risk on the biorefinery due to the potential of excess feedstock relative to its capacity constraint. Not accounting for either the ability of the biorefinery to purchase feedstocks from other sources when yields on contracted acreage are low, or for potential secondary markets for excess feedstock produced is a limitation of this study.

The results found in this analysis are generally similar to other studies after adjusting for differences in crops, time-frame, and technological assumptions. The contract prices calculated here are similar to those used by De La Torre Ugarte *et al.*, 2003; English *et al.*, 2006; and Epplin *et al.*, 2007. While most of the previous economic research done in delivering biomass has focused on wood wastes and switchgrass, this research focuses on new hybrid varieties of sorghum and sugarcane. If these crops can deliver the proposed yields on a consistent, commercial basis, then they may offer a suitable biomass alternative once cellulosic fuel production becomes commercially viable.

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