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Cellulosic ethanol in Louisiana: a three part economic analysis of feedstocks, pricing strategies and location strategies

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CELLULOSIC ETHANOL IN LOUISIANA: A THREE PART ECONOMIC ANALYSIS OF FEEDSTOCKS, PRICING STRATEGIES AND LOCATION STRATEGIES

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
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in
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by
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ABSTRACT

The development of an efficient biomass supply chain is pivotal for the cellulosic ethanol industry. The Louisiana Sugarcane Belt, and energy cane are the focus of this study. From both the producer and processor perspectives, cost of production, competitiveness of cellulosic ethanol, biomass pricing, changes in crop mix, and the optimal location for cellulosic ethanol processing facilities are the critical factors evaluated.

Educating potential energy cane producers on production costs and agronomic practices is the first step in the biomass supply chain. This study finds that for energy cane producers to breakeven, processors need to pay producers at least $30 per ton of biomass. The breakeven price producers require, decreases if new varieties with higher yields and for a longer sustained production cycle are developed. These new varieties also help to increase the competitiveness of the cellulosic ethanol industry relative to the corn ethanol industry by driving down feedstock and transportation costs.

For processors to induce the production of energy cane they have to provide producers with expected net returns per acre that are at least equivalent to that of sugarcane. Numerous methods on pricing biomass exist but this study investigates variable pricing strategies, based on corn, crude oil, and ethanol prices, and a two-tiered hybrid strategy that guarantees a portion of production cost plus a fixed amount per ton of biomass production. Results indicated that none of the pricing strategies induce the production of energy cane relative to sugarcane, but minor adjustments to the ethanol and hybrid strategies makes them viable options for processors.

Depending upon the pricing strategy implemented, producers alter crop allocation decisions to maximize net returns per acre. Primarily rice and soybean acres in the region decline allowing for the production of energy cane. As the crop mix changes in the region, the cost minimizing location for a cellulosic ethanol plant changes. Results indicate that for a single processor operating Belt the optimal location is St. Landry Parish. Increasing the number of processors in the region to two, decreases total transportation costs decrease and the optimal locations for the plants are Acadia and Pointe Coupee Parishes.

CHAPTER 1: INTRODUCTION

The use of ethanol as an energy source in the United States dates back to the 1850s, when ethanol was used as a lighting fuel. In an effort to raise money for the Civil War, the Union Congress imposed a $2.00 tax, in 1862, which made the use of ethanol as a lighting source prohibitively expensive (EIA, 2005). After the repeal of the tax in 1906, the United States saw a resurgence of ethanol as an energy source not as a lighting fuel but instead in the automotive industry. The Ford Model T was designed to run on ethanol produced by American farmers, owing to Henry Ford's desire to produce a vehicle affordable for the working family and powered by a fuel that would boost the rural farm economy (NESEA, 2008).

The entry of the United States into World War I in 1917 further spurred the demand for ethanol to 50-60 million gallons per year, due to the scarcity of other fuel sources (EIA, 2005). With the arrival of Prohibition in 1919, demand declined as the new laws labeled ethanol as 'liquor' and banned its production unless blended with petroleum. This created the perfect opportunity for gasoline producers to establish a stronghold on the liquid fuel industry (EIA, 2005). By the time of Prohibition's repeal in 1933, gasoline manufactures had gained significant market power and established rigid supply chains. Even though there were some 2,000 plus service stations in the Midwest that sold ethanol in 1930s, the low petroleum prices of the 1940s effectively meant the demise of a nationwide ethanol industry (NESEA, 2008).

World War II demand for more diversified fuel sources leading to the investment of time, effort, and money into the production of ethanol and construction of the first United States ethanol plant in Omaha, Nebraska, by the United States Army (EIA, 2003). The purpose of this plant was to supply fuel to the Army, due to the oil shortage created by territorial shifts in the war, and to supply ethanol to the Midwest for blending with petroleum. At the end of World War

II, petroleum prices fell again, as did the Army's demand for ethanol. The new period of low demand for ethanol continued until the Organization of the Petroleum Exporting Countries (OPEC) embargo of 1973.

In 1973, OPEC raised the price of crude oil by 70%, placed an embargo on the United States, and threatened to decrease production by 5% per month until Israel withdrew from Palestine (EIA, 2003). The embargo reignited domestic interest in ethanol as the U.S. began to think about energy independence for the first time, beginning the formation of the modern ethanol policy era.

In addition to energy independence, with ethanol being one of the potential fuels, there were several other issues that the United States wanted to address, such as public health, the environment, and the economy (CDFC, 2003). Figure 1.1 outlines the issues, goals, and expected results that the United States set out to achieve within the ethanol policies detailed in Figure 1.2. Prior to 1973, discussions had already begun on how to address these issues.

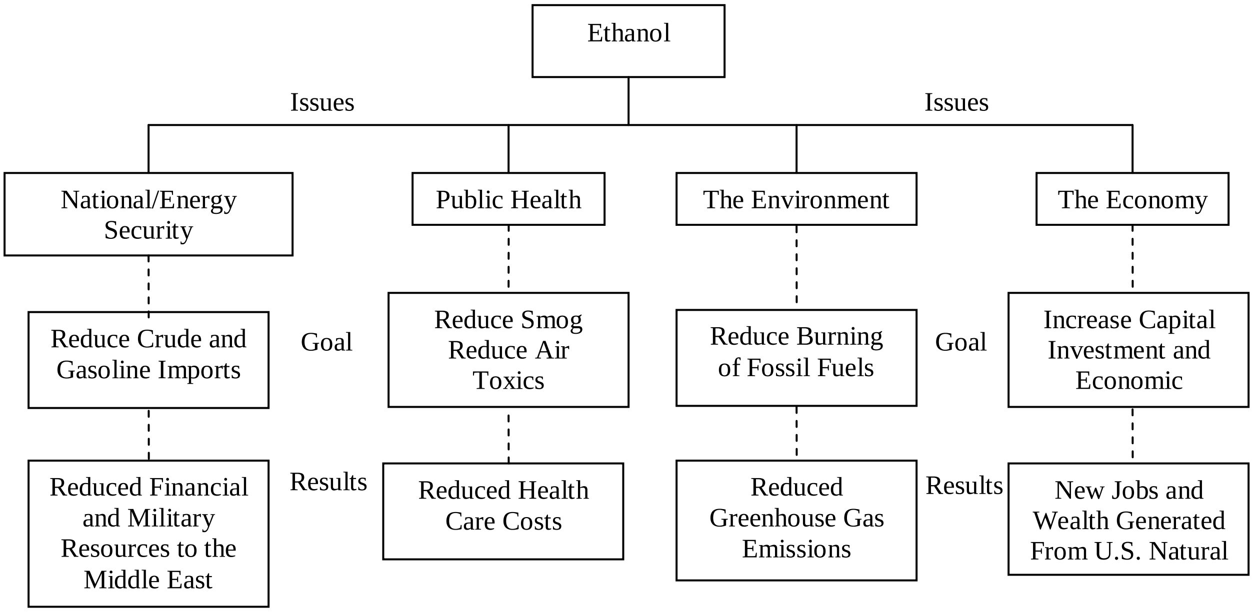

Figure 1.1: Modern Ethanol Policy Issues, Goals, and Expected Results

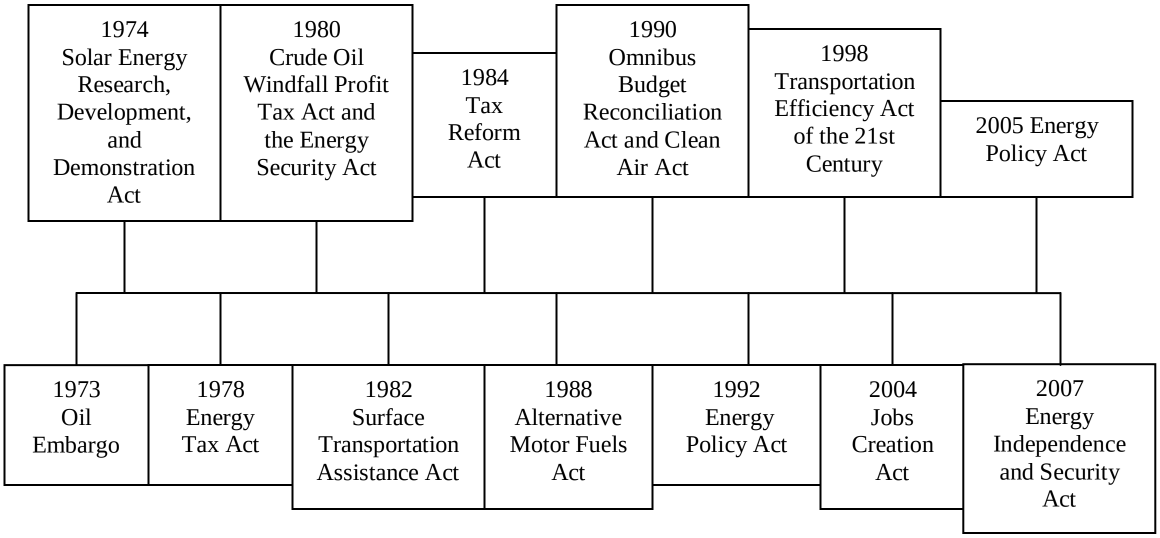

Figure 1.2 Timeline of Ethanol Policies

With the passing of the Solar Energy Research, Development, and Demonstration Act in 1974, ethanol for the first time, since the invention of the Model T, it was promoted as a fuel. The act also included research and development of conversion processes for cellulosic and additional organic materials. As of January 2010, however, there are no commercial cellulosic plants in operation to date, compared to 189 traditional (i.e. fermentation ethanol) ethanol plants operating and another 11 either under construction or expanding (RFA, 2010). Again, in 1975, the allure of using ethanol became stronger as an additive to boost the octane in gasoline, as the United States begins to phase out the use of lead in gasoline.

The first monetary incentives for the production of ethanol in the United States came in 1978 with the ratification of the Energy Tax Act, thus setting the stage for many subsequent ethanol policies to provide subsidies. A key feature of this act was that it defined the hybrid fuel, gasohol, to be a blend of at least 10% alcohol by volume. Since the alcohol could not be petroleum-based, ethanol arose as the clear choice because of its renewable characteristics (EIA, 2003). The primary crop used to produce ethanol is corn.

Compared to other feedstock, corn is relatively cheap and abundant. These characteristics provided the best choice for producing ethanol. Furthermore, the fermenting technology needed to produce ethanol from corn had been around for decades. The Energy Tax Act also provided a $0.40 per gallon subsidy for every gallon of ethanol mixed with gasoline (EIA, 2003). Within the first year of the passing of this bill, many of the oil companies launched marketing campaigns for gasohol (EIA, 2005). In 1980, the $0.40 per gallon ethanol subsidy was extended with the passing of the Crude Windfall Tax Act. With concurrent increases in automobile usage and the implementation of a tariff on foreign oil, growth in the ethanol industry continued (EIA, 2003).

From 1980-1983, the ethanol industry continued to grow at an average growth rate of 74% per year. In 1983 and again in 1984, with the passing of the Surface Transportation Assistance Act of 1982 and the Tax Reform Act of 1984, the subsidy was increased from $0.40 to $0.50 and then $0.60 per gallon of ethanol, respectively (EIA, 2005). However, even with the subsidy, only 45 percent of the current 163 ethanol plants were operating nationwide. These plants generated approximately 595 million gallons per year (EIA, 2003). During this time, there were a large number of plant failures, which were attributed to poor business decisions, questionable engineering, low crude oil prices, and supply outpacing demand. The high number of plant failures slowed the expansion of annual ethanol production to an average of 18% per year or 685 million gallons annually from 1984 to 1988.

A further stimulant to demand for ethanol, the Alternative Motor Fuels Act, was ratified in 1988. This act also created research and development opportunities for automotive companies to explore the development of what are known today as “flex fuel” cars. In addition to national energy security and the economy, this act focused on public health, environmental issues, vehicles that emitted lower emissions, and increasing air quality. Mandates on the usage of oxygenated fuels to control carbon dioxide emissions started in Denver, Colorado, in 1988 (EIA, 2003).[1]

The first decrease in the ethanol subsidy came with the passing of the Omnibus Budget Reconciliation Act in 1990, from $0.60 to $0.54 per gallon. The act extended the subsidy through 2002. Additionally in 1990, the Clean Air Act was ratified, with its main objective being to decrease the pollution created by vehicle emissions. The act called for decreased fuel emissions in highly polluted cities, such as Los Angeles, through the use of cleaner burning oxygenates (EIA, 2003). The 1992 Energy Policy Act increased the range of ethanol blends eligible for receipt of a subsidy. The subsidy, however, was prorated depending on blend, i.e. the subsidy paid on a 5% blend is less than a 10% blend (EIA, 2005). Furthermore, this act called for all new government vehicles purchased to be flex-fuel vehicles, with the goal of achieving a 30% market penetration by 2010 (CDFC, 2003). The passage of the Transportation Efficiency Act of the 21st Century in 1998 extended the subsidy through 2007, with three cents per gallon decrease taking effect in 2005.

The 1999 discovery of methyl tertiary butyl ether (MTBE) in groundwater prompted individual states (e.g. Arizona, California, Colorado, Connecticut, etc.) to implement bans phasing out or limiting the usage of MTBE in the states gasoline (EPA, 2004). Then in 2000, the Environmental Protection Agency recommended the phasing out of MTBE nationwide (EIA, 2005). This set in motion a time of tremendous growth for the ethanol industry. Until this point, MTBE was the primary oxygenate, but with its phasing out a market opportunity for ethanol arose. One of the largest increases in ethanol demand came in 2003, with the phasing out period of California’s banning of MTBE. California switched to the blending of ethanol in its

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[1] Typical oxygenates used in 1988 were Methyl Tertiary Butyl Ether (MTBE), Ethyl Tertiary Butyl Ether (ETBE), and ethanol.

reformulated gasoline (EIA, 2003). Other states such as New York and Connecticut were also in the process of making the transition from MTBE to ethanol (EIA, 2005). The ban on MTBE created a complete paradigm shift in the ethanol industry. Prior to 2003, ethanol accounted for less than half of the United States oxygenates market, but by 2007, its market share had risen to 87% (EIA, 2008).

The passage of the Jobs Creation Act in 2004 changed the mechanism for receiving the subsidy and once again extended the subsidy through 2010 (Tyner, 2007). Another significant boost to ethanol demand occurred with the passage of the Energy Policy Act in 2005. This act established the Renewable Fuels Standard (RFS), mandating 4 billion gallons of ethanol be produced by 2006 and rising to 7.5 billion gallons by 2012 (Tyner, 2007). The RFS has continued to drive the ethanol industry expansion; with both of these mandated levels being surpassed before their deadline. A new RFS2 was passed in 2007, with the ratification of the Energy Independence and Security Act (EISA), mandating that fuel producers use at least 36 billion gallons of biofuels by 2022 (OPS, 2007). Table 1.1 details the timing and mandated volumes for the different types of biofuels defined under the RFS2 (RFA, 2010). The mandated increase in cellulosic ethanol production from 100 million gallons in 2010, that was never achieved, to 16 billion gallons by 2022 requires the development of an efficient biomass supply chain.

Table 1.1: Renewable Fuels Standard 2 Schedule (Billion Gallons per Year)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Renewable Biofuel	9.0	10.5	12.0	12.6	13.2	13.8	14.4	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Advanced Biofuel		0.6	1.0	1.4	2.0	2.8	3.8	5.5	7.3	9.0	11.0	13.0	15.0	18.0	21.0
Cellulosic Biofuel			0.1	0.3	0.5	1.0	1.8	3.0	4.3	5.5	7.0	8.5	10.5	13.5	16.0
Biomass-based Diesel		0.5	0.7	0.8	1.0										
Undifferentiated Advanced Biofuel		0.1	0.2	0.3	0.5	1.8	2.0	2.5	3.0	3.5	4.0	4.5	4.5	4.5	5.0
Total RFS	9.0	11.1	13.0	14.0	15.2	16.6	18.2	20.5	22.3	24.0	26.0	28.0	30.0	33.0	36.0

The passage of EISA continues to drive ethanol production as shown in Figure 1.3. Furthermore, EISA places an emphasis on the production of cellulosic ethanol with the mandate of 16 billion gallons by 2022. This will be a significant hurdle for the industry, given the fact that there is no commercially produced cellulosic ethanol in the United States. For this industry to develop, several key questions must be answered about production costs, pricing of biomass, biomass production effects on net returns, changes in crop mixes, and location of processing plants.

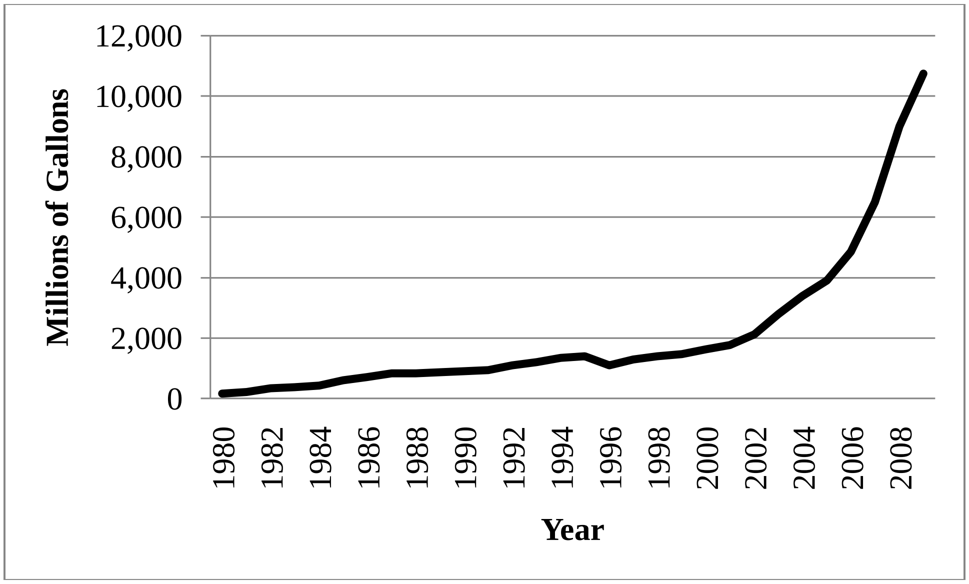

Figure 1.3: Historical United States Ethanol Production

Purpose

The purpose of this study is to investigate the potential development of a biomass supply chain for the creation of a cellulosic ethanol industry in Louisiana, based upon the production of energy cane. Specifically, my research takes a ground up approach to supply chain development and examines production costs, pricing of biomass, biomass production effects on net returns, changes in crop mixes, and location of processing plants from the perspective of either the producer or the processor. Information and results derived from this research will provide producers, processors, policy makers, and stakeholders with knowledge of key variables needing consideration for the development of a biomass supply chain.

Objectives

Paper 1

Many of the crops (e.g. mischantus, energy cane, reed canarygrass, big bluestem) being considered for biomass have not been grown in Louisiana or in most other regions of the country traditionally. Therefore, potential producers of these crops are unfamiliar with the production practices and markets for these biomass crops. The development of a biomass supply chain will be dependent upon providing producers with the information necessary for them to make production decisions. The first objective is to determine the breakeven prices needed by sugarcane producers to cover costs of production for energy cane. This objective focuses on the starting point of the supply chain.

For the cellulosic ethanol industry to develop, it must be competitive with corn ethanol. To accomplish this, a holistic approach of the two industries is considered. The second objective is to evaluate the competitiveness of the cellulosic and corn ethanol industries. In particular, this objective determines how increasing energy cane yield (t/ac) and corn price influence cellulosic ethanol's competitiveness.

Paper 2

Another key to the development of a biomass supply chain is determining how biomass will be priced. Unlike corn or other cash grain markets, there are no precedents for how biomass should be priced in the market place. Both producers and processors are beginning to speculate as to how the market might work. In general, the pricing strategy chosen will have to provide producers with at least the same expected returns per acre as their current crops are providing. The first objective of this paper is to compare different potential pricing strategies and their influence on a producer's expected net returns per acre.

To further the investigation of pricing strategies, risk preferences for producers is introduced into the model. Many of the potential pricing strategies could be based on volatile markets such as the crude oil, ethanol, or corn markets. Therefore, the second objective is to investigate which pricing strategy induces the production of energy cane based upon a producer's risk preferences.

Paper 3

The introduction of energy crops into the farmers' portfolio of the available crops to produce could have significant impacts on the agricultural landscape. The implementation of an appropriate pricing strategy, will likely result in the change in crop mix for a parish, a state, a region, or nation. Understanding how crop mixes change by location is key for the cellulosic ethanol industry because transportation costs for biomass are a crucial driver of profitability. The first objective is to project the potential changes in the crop mix, given various pricing strategies used by processors to entice producers to switch into the production of energy cane.

Changes in the crop mix for a parish, state, region, or nation can have a significant influence on the optimal plant locations for the cellulosic ethanol industry. In general, biomass is expensive to transport because of its high moisture content, especially in the case of energy cane and sweet sorghum. Therefore, cellulosic ethanol plants may find it beneficial to locate close to potential biomass sources. The second objective is to determine optimal cellulosic ethanol plant location(s) based on the crop mix of the Sugarcane Belt.

Study Area

This study focuses on the Louisiana Sugarcane Belt, as farmers in this region are looking for additional crops to add to their portfolio, given stagnant sugar prices and rising input costs. The Sugarcane Belt of Louisiana consists of 22 parishes in Southern Louisiana. The Sugarcane Belt is unique because the only crops produced in the belt are sugarcane, rice, and soybeans, whereas, in other production areas, such as the Midwest, there are many more crops available for use in the crop rotation. This region also has the advantage of having existing harvest and transportation equipment, as well as producer expertise in growing a high biomass crop. These advantages allows a framework to be developed and validated on a small scale before it is expand to encompass larger and more diverse regions of the United States.

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CHAPTER 2: ENERGY CANE USAGE FOR CELLULOSIC ETHANOL: ESTIMATION OF FEEDSTOCK COSTS

Introduction

Significant energy policies influencing the expansion of the ethanol industry include the banning of Methyl Tertiary Butyl Ether (MTBE), the 2005 Energy Policy Act, and the 2007 Energy Independence and Security Act (EISA). The designated phasing out of MTBE in 2000 created an opportunity for ethanol to become the primary oxygenate used in the production of gasoline (EIA, 2005). The 2005 Energy Policy Act established a Renewable Fuel Standard (RFS), mandating 4.0 billion gallons of biofuels be produced annually by 2006 and rising to 7.5 billion gallons annually by 2012 (Tyner, 2007). Both of these mandated levels were surpassed before their deadline, creating the need for a new RFS. A new RFS was passed in 2007 with the ratification of EISA, which mandated that fuel producers use at least 36 billion gallons of biofuels by 2022 and placed an emphasis on the production of cellulosic ethanol (OPS, 2007). The addition of cellulosic ethanol could result in biofuels becoming a significant player in the overall U.S. energy portfolio.

In 2009, 13.2 billion bushels of corn were produced on 79.6 million agricultural acres in the U.S. (USDA, 2010). If all of this corn were converted into ethanol, it would only produce enough fuel to last about 64 days, given the 2009 level of 9 million barrels of gasoline consumed per day (EIA, 2007).[2] Approximately 12.9 billion bushels of corn would be required to fulfill the 36 billion gallons of biofuels needed by 2022, if it was the only source of ethanol. The usage of corn at this level for ethanol is not sustainable, given the other demands for corn as feed grains in the livestock industry, the food and fiber system, and in the export market.

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[2] A conversion ratio of 2.8 gallons of ethanol per bushel is assumed (Schnitkey et al., 2007)

Each region or state within the United States should produce the energy crop for which it has a competitive advantage, if the mandated levels of biofuel production are too be reached. For example, in the Midwest, corn should continue to be the crop of choice, while for states in the South, other biomass crops may be a more efficient and effective energy crop choice. High-fiber energy cane could be that crop in Florida, Louisiana, and Texas. While energy cane and sugarcane are the same genus, *saccharum*, energy cane is bred for high fiber content and sugarcane is bred for low fiber content but high sugar content. Table 2.1 contains the tons of cane harvested per acre, the percentage of sugar by mass (i.e. brix), and the percentage of insoluble material delivered for processing (i.e. fiber) for two energy cane varieties (Ho 00-961 and HoCP 91-552) compared with a traditional sugarcane variety (LCP 85-384) (Rein, 2006).

Table 2.1: Brix and Fiber Comparison of a Standard Sugarcane Variety and Two Energy Cane Varieties

Variety	**Gross Cane (t/ac)**	**Brix (% Cane)**	**Fiber (% Cane)**
LCP 85-384 a/	**31.5**	**18.2**	**13.0**
Ho 00-961 b/	34.6	17.7	15.9
HoCP 91-552 b/	38.9	16.8	15.2

a/ Dominant Louisiana Sugarcane Variety. b/ High-fiber energy cane variety.
Source: ASCL, 2007a; 2007b

Since cellulosic technology is still in the developmental phase, few companies (e.g. Abengoa, Broin, Iogen, and Verenium) are currently experimenting with producing ethanol from cellulosic materials (e.g. wheat, switchgrass, forestry products). The town of Jennings, Louisiana, is home to Verenium’s pilot plant, which is using sugarcane bagasse in a cellulosic ethanol process. According to the Renewable Fuels Association (2008), there is a potential of 1.3

billion tons of sustainable cellulosic material that could produce an estimated 60 billion gallons of ethanol annually in the United States. Additionally, the majority of this potential biomass is to be harvested from second-generation feedstocks, which are feedstocks that are not used for foods (BR&Di, 2008).

Many of the feedstock crops being considered for use in the production of cellulosic ethanol, including energy cane, are nontraditional crops, with the exceptions of switchgrass and corn. Switchgrass can be used to pasture or produce feed for livestock, and corn residue can be collected for conversion into ethanol. [3]

The production of nontraditional crops however, creates a situation in which producers are uncertain about the production costs and the breakeven prices needed to maintain production. According to Beierlein et al. (1995), breakeven analysis can be used effectively as a “first screening procedure” or “ballpark technique” for a top-level examination. Khanna et al. (2008) employ a Net Present Value (NPV) framework to determine the breakeven price required to cover the cost of production for both switchgrass (10-year time horizon) and miscanthus (20-year time horizon). Hallam, Anderson, and Buxton (2001), also use a breakeven analysis to determine the required price needed to cover the total production costs for reed canarygrass, switchgrass, big bluestem, alfalfa, sweet sorghum, forage sorghum, and maize.

In an effort to apply and advance this technique, this paper has two objectives: 1) to determine the breakeven price producers must receive to cover energy cane’s cost of production and 2) to determine how increasing energy cane yield (t/ac) and price of corn impacts cellulosic ethanol’s competitiveness with traditional corn ethanol.

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[3] Corn residue is the organic material remaining on the field surface after harvesting the grain. Typically, this organic material has been incorporated back into the soil, but with the development of the cellulosic ethanol industry it is being considered as a potential feedstock for the industry (DeJong-Hughes and Coulter, 2009)

Materials and Methods

Florida and Louisiana are the largest producers of sugarcane in the United States, with 390,000 and 425,000 acres in 2009, respectively (USDA, 2010). An established sugarcane production, harvest, transportation, and processing infrastructure, as well as energy cane's ability to produce substantial amounts of biomass per acre, are key reasons for the attractiveness of the crop in the region (Alexander, 1985). Energy cane is lower in sucrose or brix content, but higher in fiber content than traditional sugarcanes varieties (e.g. LCP85-384). Table 1 showed a comparison between energy cane varieties Ho 00-961 and HoCP 91-552 released in 2007 compared to LCP85-384, the predominate variety of sugarcane grown in Louisiana (ASCL, 2007a; 2007b). An additional energy cane variety, L 79-1002, has also been released, but to date there is no research plot yield data available. There have been reports, however, of this variety yielding over 100 t/ac, which is significantly higher than the 35 t/ac current varieties are yielding (ASCL, 2007c). Furthermore, the cellulosic ethanol industry is still in its infancy stages, and commercial processing facilities for this biomass are not operational.

Currently, no commercial cellulosic ethanol processing facilities are operating. Feedstock production costs/breakeven data must be estimated because no actual data is available. The *2010 Sugarcane Production in Louisiana* costs and returns report provides the budget data used for determining production costs and breakeven prices required in the production of energy cane (Salassi and Deliberto, 2010). All assumptions made in the report are applied in this study with only minor modifications made to the original costs and returns budget. These modifications reflect the assumption that growers will no longer be paid on the sugar content of the crop, but rather on the total biomass delivered to the processor.

Grower Breakeven Costs

This research considers the price a biofuel facility/biomass processor should pay biomass feedstock growers in order for them to cover variable, fixed, overhead, land rental, and transporting costs (i.e. breakeven). Breakeven price is determined using equation 2.1,

$$BE = \left(fixed + variable + overhead \right) \Big/ \left(\left(harvested / 100 \right) * tonsperac \right), \qquad (2.1)$$

where *BE* is the breakeven price in \$/t, *fixed* is the fixed cost \$/ac, *variable* is the variable cost \$/ac, *overhead* is the overhead costs in \$/ac, *harvested* is the acres harvested, and *tonsperac* is the average t/ac harvested on the operation. Given the similarities between energy cane and sugarcane, it is expected that production cost between the two will be similar. Furthermore, as yields for energy cane increase, the breakeven price will decrease as producers spread costs out over larger tonnages.

Additional assumptions for the model are a one-sixth crop share land rental charge paid by growers to landlords and a payment from the processor to the producer of an average value of \$3.50 per ton for transportation credit from farm to mill (Salassi and Deliberto, 2010). These assumptions are based on the typical land rental and average hauling distances observed in the sugarcane industry and used in current enterprise production cost sugarcane budgets for Louisiana. The true yield potential of energy cane is unknown at this time because research and development of energy cane varieties is in its infancy. For the purposes of this analysis, a range of 30 to 70 tons per acre (t/ac) is analyzed and harvesting costs are changed to reflect the increased yields (ASCL, 2007).[4]

Since energy cane is a perennial crop, growers have minimal flexibility to increase or decrease the stubbling lengths of the crop, which are dependent upon the planted variety.

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[4] Harvesting costs are based on the assumption of 45 tons per hour can be harvested (Barker, 2007).

Stubbling length simply refers to the length of the crop cycle, i. e., the number of annual harvests possible before replanting is necessary. For example, if an operation harvests through third stubble, a five-year production cycle is being used. Two different stubbling lengths are examined in this study (third and fourth stubble). Before proceeding with the analysis, it is important to understand the expansion and production processes of sugarcane or energy cane. In the next three sections, these processes are discussed in-depth.

Seed Cane Expansion

Equations 2.2 - 2.7, describe the seed cane expansion process of energy cane, a process similar to that of sugarcane. Energy cane, like sugarcane, is a vegetatively propagated crop. Acres are expanded on farms over a three-year period. Figure 2.1 provides a visual description for this expansion process.

Equation 2.2 represents the purchasing of tissue cultured seed cane to be planted,

$$cscplt_t = cschrv_{t+1}, \tag{2.2}$$

where $cscplt$ is the acres of tissue cultured seed cane planted and t is time. This initial planting of $cscplt_t$ is harvested twice for expansion. The first harvest takes place in the following year $cschrv_{t+1}$. Equation 2.3 shows how this is then expanded,

$$1^{st}\ exppcplt_{t+1} = cschrv_{t+1} * pltratio_h, \tag{2.3}$$

where $1^{st}\ exppclplt_{t+1}$ is the first expansion of seed cane and $pltratio_h$ is the hand planting ratio. The expansion process of sugarcane uses different ratios of acres that one acre of seed cane is expanded to depending upon the planting ratio the operation employs. Typically, this first expansion is replanted via a hand planted whole stalk method. A planting ratio of five tons of $cschrv_{t+1}$ are planted per acre. Equation 2.4, represents the second expansion,

$$2^{nd}\ exppcplt_{t+2} = 1^{st}\ exppchrv_{t+1} * pltratio_m, \tag{2.4}$$

where 2^{nd} $exppcplt$ is the second expansion and $pltratio_m$ is the mechanical planting ratio. The difference with this expansion is $pltratio_m$ is employed and it requires seven tons of $1^{st}exppcplt$ per acre of 2^{nd} $exppchrv$. It should be noted that this ratio varies by variety of cane (for more details see Salassi and Breaux, 2001). Equation 2.5 follows the same expansion path for first stubble,

$$1^{st}\ exp1stub_{t+2} = cshrv_{t+2} * pltratio_m, \tag{2.5}$$

where 1^{st} $exp1stub_{t+2}$ is the first expansion of first stubble energy cane. Equation 2.6 represents the third and final expansion,

$$2^{nd}\ exp1stub_{t+3} = 1^{st}\ exp1stubhrv_{t+2} * pltratio_m, \tag{2.6}$$

where 2^{nd} $exp1stub_{t+3}$ is the third expansion using the mechanical planting ratio. The perennial nature of this crop requires $cscplt$ to be planted yearly. To determine the amount of sugarcane (energy cane) to be planted each year $cscplt$ equation 2.7 is used,

$$cscplt_t = fallow_{t-1}/(1+(2*pltratio_h)+(2*pltratio_h*pltratio_m)), \tag{2.7}$$

where $fallow$ is the fallow land in the previous year. This equation calculates the amount of planted acreage needed by starting with the acres of fallow land ($fallow$). In sugarcane production, fallow acreage represents farm acreage on which the oldest stubble has been plowed out and the land is left fallow until it is replanted. Then, dependent upon the planting ratios ($pltratio_h$ and $pltratio_m$), $cscplt_t$ is determined. For crop cycles through harvest of third and fourth stubble, 200 acres and 166 acres, respectively, of total farm acreage are fallow each year, based on a total farm size of 1,000 acres.

Harvest Rotation

The second phase of energy cane production is to determine the harvesting rotation for the farm. The harvesting rotation will vary by farm, variety, and management strategy employed.

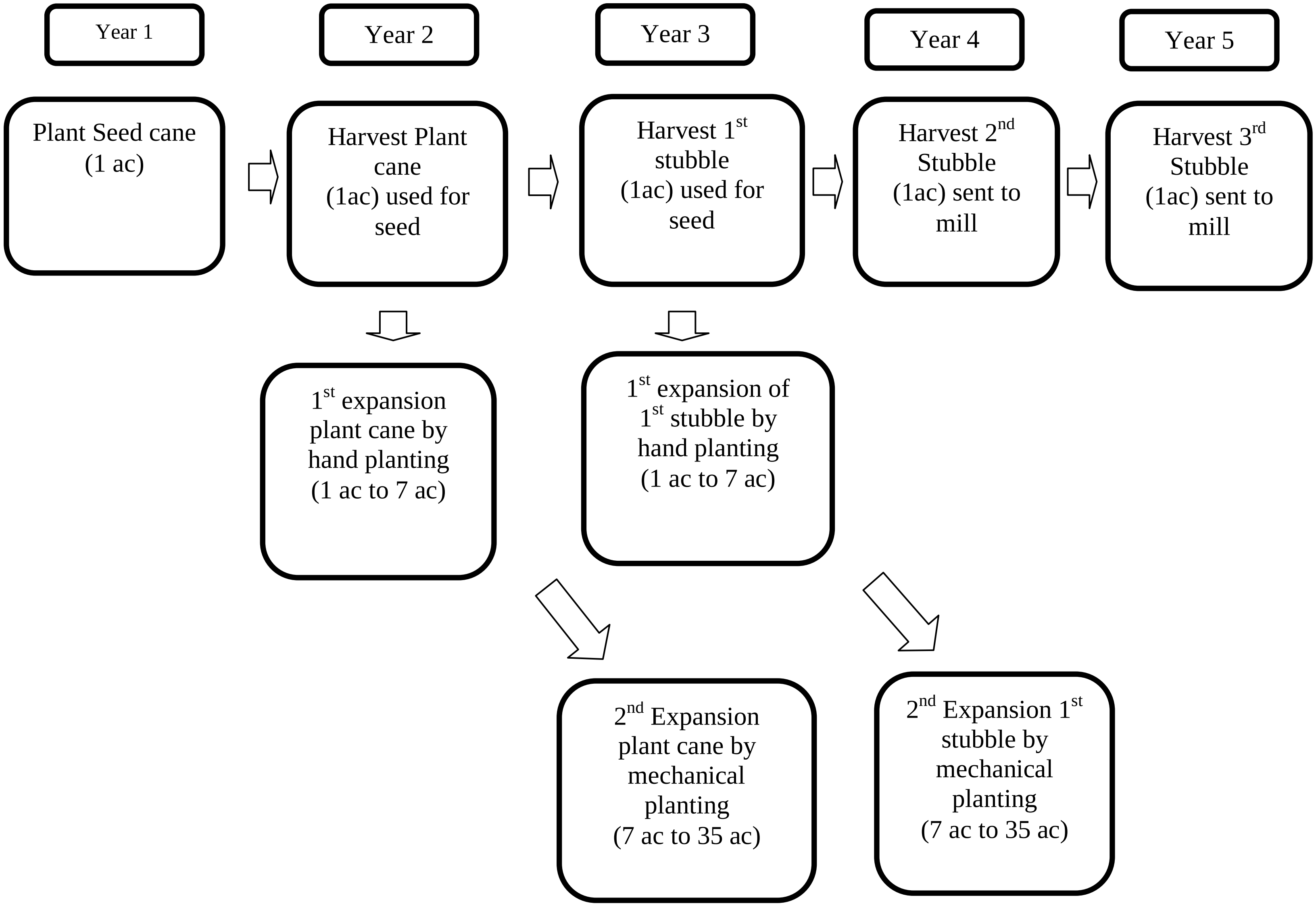

Figure 2.1: Sugarcane/Energy Cane Seed Cane Expansion Process - One-Acre Example

For example, on a representative farm, harvesting through 3rd stubble, the land area is divided equally into five different stages of production. These stages of production include plant cane (*pchrv*), first stubble (*1sthrv*), second stubble (*2sthrv*), third stubble (*3sthrv*), and fallow ground. Equation 2.8 shows how each of these different stages of production flow through the system on a single 1,000 acre farm over time,

$$pcplt_t = pchrv_{t+1} = 1sthrv_{t+2} = 2sthrv_{t+3} = \ldots = msthrv_{t+m+1}, \tag{2.8}$$

where *m* is the number of stubble/ratoon crops. Fallow ground is omitted from this because no actual production takes place on this land, and the typical rotation will leave the ground fallow for one year. In the case of an operation that is harvesting through third stubble every year, 20% (200 acres) of the 1,000 acres would be fallow.

Farm Acreage

The third phase is to determine how the farm acres are allocated to each of the different stages of energy cane production. At any point in time, not all acres are in production because a portion of the land remains fallow. Equation 2.9 summarizes the total planted acres,

$$totplt_t = tacres_t / (n+1), \tag{2.9}$$

where *totplt* is the total acres on the farm and *n* represents the stubbling length chosen for the operation. Equation 2.10 further breaks down planted acres,

$$totplt_t = cscplt_t + 1^{st}exppcplt_{t+1} + 2^{nd}exppcplt_{t+2} + 1^{st}exp1stub_{t+2} + 2^{nd}exp1stub_{t+3}, \tag{2.10}$$

where $totplt_t$ is the total acres planted for each of the different expansions of energy cane. Equation 2.11, summarizes the total harvested acres,

$$totharv_t = harvseed_t + harvbiomass_t, \tag{2.11}$$

where *totharv* is the total acres harvested, $harvseed_t$ is acres harvested for seed, $harvbiomass_t$ is acres harvest for biomass on a yearly basis. Equation 2.12, allows for the further disaggregation of acres harvested for seed,

$$harvseed_t = cscplt_{t-1} + 1^{st}exppcplt_{t-1} + 2^{nd}exppcplt_{t-1} + 1^{st}exp1stub_{t-1} + 2^{nd}exp1stub_{t-1}, \quad (2.12)$$

where *harvseed* is the acres of cane harvested for seed from each of the different phases of production. Equation 2.13, breaks down biomass production in each stage of production,

$$harvbiomass_t = pchrv_t + 1sthrv_t = 2sthrv_t = \ldots = msthrv_t, \quad (2.13)$$

where $harvbiomass_t$ is tons of harvested biomass from $pchrv_t$ to m stubbles/ratoon crops.

Comparison Between Cellulosic and Corn Ethanol

The production costs for corn ethanol and cellulosic ethanol are substantial, but in recent years, the gap between them has been narrowing, as a result of decreasing enzyme and preprocessing costs (Collins, 2007 and Aden et al., 2002). For example, in 2007 production cost per gallon for cellulosic ethanol were estimated to be $2.65 (Collins, 2007). By 2010, they are expected to decrease to between $1.07 and $1.10 (Collins, 2007; Aden et al., 2002). Collins (2007) found that on a percentage basis, capital and enzyme costs were significantly larger portions of the production costs of cellulosic ethanol compared to traditional ethanol. Furthermore, the byproducts currently produced by the cellulosic ethanol industry are not as valuable as the dried distillers' grains (DDGs) being produced in the corn ethanol industry. The major agricultural crop used for ethanol production in the United States, corn, is the benchmark comparison for cellulosic ethanol. Ethanol production per ton of biomass varies depending on the pretreatment process and the enzyme technology used. For this research, a Lignocellulic Ethanol Process with an alkaline pretreatment process is assumed for the cellulosic portion of the process, while juice from the energy cane is fermented using traditional ethanol methods. Under this production technology, it is assumed that each ton of energy cane produces 25 gallons of ethanol. The ethanol yield per ton can be broken down into sucrose juice ethanol (13 gal/t) and cellulosic ethanol (12 gal/t) (Day, 2010). The total cost for cellulosic ethanol production is determined using equation 2.14,

$$TC = FC + BP + EC + OC + CC \tag{2.14}$$

where *TC* is total costs, *FC* is feedstock costs, *BP* is byproduct revenue, *EC* is enzyme costs, *OC* is other costs, and *CC* is capital costs.

Feedstock procurement accounts for over 70% of the cost of production for corn ethanol, therefore, two different corn prices are investigated. One corn price is \$3.70 per bushel, which is the average price of corn in the United States for 2009 (USDA, 2010). The second price investigated is \$7.00 per bushel, which is representative of the high corn price observed in 2007 (USDA, 2010). Collins (2007) and the National Renewable Energy Laboratory (2002) provide the base byproduct, enzyme, capital, and other cost assumptions used in the analysis for both production processes.

Results

Producer Breakeven

Viability of energy cane as a cellulosic ethanol feedstock is dependent on the producer's ability to control costs and the development of new varieties with increased yields and longer stubbling lengths. The price producers receive varies by ton per harvested acre and length of stubbling (tables 2.2 and 2.3). As length of stubbling increases, the breakeven price required to cover production cost decreases for two reasons: 1) planting costs are spread over more years of production; and 2) a smaller percent of total land is devoted to seed cane production. Additionally, as the rate of tons per harvested acre increases, the breakeven price required decreases.

For this newly developing biofuel feedstock industry to take current production acres away from the mature sugarcane industry and from other crops, energy cane production has to provide growers with at least the same expected net return per acre that sugarcane provides. One way to evaluate this is through a comparison of expected net returns per acre for crops in the region. In recent years, increasing input costs have driven down the expected net returns per acre on sugarcane. Although market returns at average yields have more than covered variable sugarcane production costs, they have not adequately covered total production costs (variable plus fixed costs). Over the period 2005 to 2009, expected net returns per acre for the average Louisiana sugarcane producer at projected total cost levels was approximately -$31 per acre (Breaux and Salassi, 2005; Salassi and Breaux, 2006; Salassi and Deliberto, 2007, 2008, 2009). However, production of sugarcane has continued because average expected net returns above variable cost of $122 per acre were projected, allowing producers to cover their costs in the short-run (Breaux and Salassi, 2005; Salassi and Breaux, 2006; Salassi and Deliberto, 2007, 2008, 2009). In 2010 however, it is expected that net return per acre will be $60, due to the significant rise in sugarcane price and decline in input costs (Salassi and Deliberto, 2010).

Table 2.2 contains the breakeven prices that would allow growers to cover costs of production, costs of production including land rent, and costs of production including land rent plus transportation costs under a five-year crop cycle (harvest through third stubble). Increasing the yield of energy cane decreases the breakeven price ($/t) to producers. The table also contains the biomass price required by producers to make them indifferent between growing sugarcane or energy cane under the increased prices expected in 2010.[5] Prior to the sugar price increase expected in 2010, the average sugarcane producer would have preferred to produce energy cane if he or she could have secured a contract for breakeven prices. The current energy cane varieties average 35 t/ac. At these tonnages, producers need to secure a production contract of at least $30.28/t to cover all costs including transportation. There is a possibility that processors could do their own trucking, decreasing the price required by producers to $26.73/t. For example, Iogen Corporation, is planning to use a third party custom hauler for the transportation of biomass from

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[5] Column labeled “2010 Situation ($0.23/lb sugar)”.

farm to processor (Iogen 2010).[6] In this scenario, producers would only be responsible for planting, growing, and harvesting the crop. Still, given the infancy of the industry, many processors are still debating as to which method works best for their operating conditions.

Attracting growers to produce energy cane for cellulosic ethanol in 2010 and beyond, could require processors to increase the price paid per ton to a level above what is necessary for producers to break even. If sugar prices remain at their current levels of $0.23 per pound, for producers to be as well off as if they had continued to grow sugarcane, processors would have to increase the contract price to $32.01 per ton.

Table 2.2: Breakeven Prices of Biomass Required to Cover Energy Cane Production Costs in a Five-Year Crop Cycle.

		3rd Stubble		
Yield/Harvested Ac (t/ac)	Breakeven Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	2010 Situation ($0.23/lb sugar)*
30	$26.15	$31.39	$34.89	$36.91
35	$22.31	$26.78	$30.28	$32.01
40	$19.45	$23.35	$26.85	$28.36
45	$17.24	$20.70	$24.20	$25.54
50	$15.48	$18.58	$22.08	$23.29
55	$14.04	$16.85	$20.35	$21.45
60	$13.00	$15.61	$19.11	$20.11
65	$11.85	$14.23	$17.73	$18.66
70	$10.99	$13.19	$16.69	$17.56

*Dollars per ton required to bring energy cane into production, given 2010 sugar prices, and covering all costs.

Table 2.3 shows the breakeven prices required for producers to cover production costs including rent and transportation for a six-year crop cycle (harvest through fourth stubble). As indicated in Table 2.2, as yield increases, producers require a lower biomass price per ton. One of the advantages for a producer to switch to a longer stubbling is that they are able to spread the initial costs of planting over more years, which helps lower the breakeven price. Another

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[6] Iogen Corporation is a biotechnology firm specializing in cellulosic ethanol. Their corporate headquarters is located in Ottawa, Ontario, Canada. They are considering expansion into the United States in the Pacific Northwest and use wheat straw in their cellulosic ethanol process.

advantage to longer stubbling lengths is that for processors more energy cane is harvested. For example, a change from 3rd stubble to 4th stubble results in an additional 34 acres harvested annually; however, yield for these 34 acres is dependent upon the variety (ASCL, 2007).

Table 2.3: Breakeven Prices of Biomass Required to Cover Energy Cane Production Costs in a Six-Year Crop Cycle.

	4th Stubble			
Yield/Harvested Ac(t/ac)	Breakeven Total Grower Cost	Breakeven Cost Including Rent	Breakeven Cost Including Hauling	2010 Situation ($0.23/lb sugar)*
30	$23.86	$28.64	$32.14	$34.16
35	$20.37	$24.45	$27.95	$29.68
40	$17.78	$21.34	$24.84	$26.36
45	$15.77	$18.93	$22.43	$23.78
50	$14.17	$17.01	$20.51	$21.72
55	$12.93	$15.52	$19.02	$20.12
60	$11.78	$14.14	$17.64	$18.65
65	$10.86	$13.04	$16.54	$17.47
70	$10.06	$12.08	$15.58	$16.44

*Dollars per ton required to bring energy cane into production, given 2010 sugar prices, and covering all costs.

Table 2.4: Difference in Breakeven Prices of Biomass Between 3rd and 4th Stubble

Yield/Harvested Ac	**Total Grower Cost**	**Breakeven Cost Including Rent**	**Breakeven Cost Including Hauling**	**Processor Savings ($/ac)**
30	($2.29)	($2.75)	($2.75)	($82.47)
35	($1.94)	($2.33)	($2.33)	($81.51)
40	($1.67)	($2.00)	($2.00)	($80.19)
45	($1.47)	($1.76)	($1.76)	($79.41)
50	($1.31)	($1.57)	($1.57)	($78.63)
55	($1.18)	($1.42)	($1.42)	($77.91)
60	($1.08)	($1.30)	($1.30)	($77.79)
65	($0.99)	($1.19)	($1.19)	($77.25)
70	($0.93)	($1.12)	($1.12)	($78.15)

The ability of producers to increase the stubbling length (third to fourth stubble) also benefits the processor by decreasing the breakeven price required by producers. Table 2.4 illustrates the decrease in breakeven prices if producers were able to increase the stubbling length. On a per ton basis, the most significant decrease in price ($2.75) occurs at 30 t/ac and on a per acre basis processors could save $82.47 per acre if they contract at breakeven prices. The savings may not seem significant, but this increase in stubbling length could reduce feedstock costs for a 10 million gallon cellulosic ethanol plant by $1.1 million.[7]

In the above section, the breakeven prices required by producers to cover different types of costs over various yield levels were discussed. In the next section, the focus of the discussion changes from producers' perspective to a more holistic ethanol industry view. Specifically, production costs for the cellulosic ethanol segment of the ethanol industry are compared to the traditional corn ethanol segment.

Corn Ethanol Production Costs vs. Cellulosic Ethanol Production Costs

Corn is the primary crop used in ethanol production and the fermentation method used to produce corn ethanol has been in use for over a century. For cellulosic ethanol to be a viable ethanol production process, it must be able to produce ethanol at a cost no greater than that of corn ethanol. Figures 2.2 and 2.3 show the competitiveness of cellulosic ethanol production costs, using the feedstock costs from a third and fourth stubbling rotation, compared to the production costs of traditional ethanol. The major areas of difference between the two production processes are found in enzymes, feedstock, and byproduct costs. The cellulosic ethanol process is heavily dependent on enzymes in the pretreatment process that break down the biomass into hemicelluloses, cellulose, and lignin.

Since the cellulosic ethanol industry is still in its infancy, many of the enzymes currently used are still in the research and development stage, thus increasing their cost. For both of the figures, enzyme costs of $0.40/gal (Projected 2007 Cellulosic) and $0.15/gal (Projected 2010 Cellulosic) are used. Under the 2007 costs of production, cellulosic ethanol is unable to compete with tradition ethanol when corn price is $3.70 per bushel (Projected Corn). However, as energy

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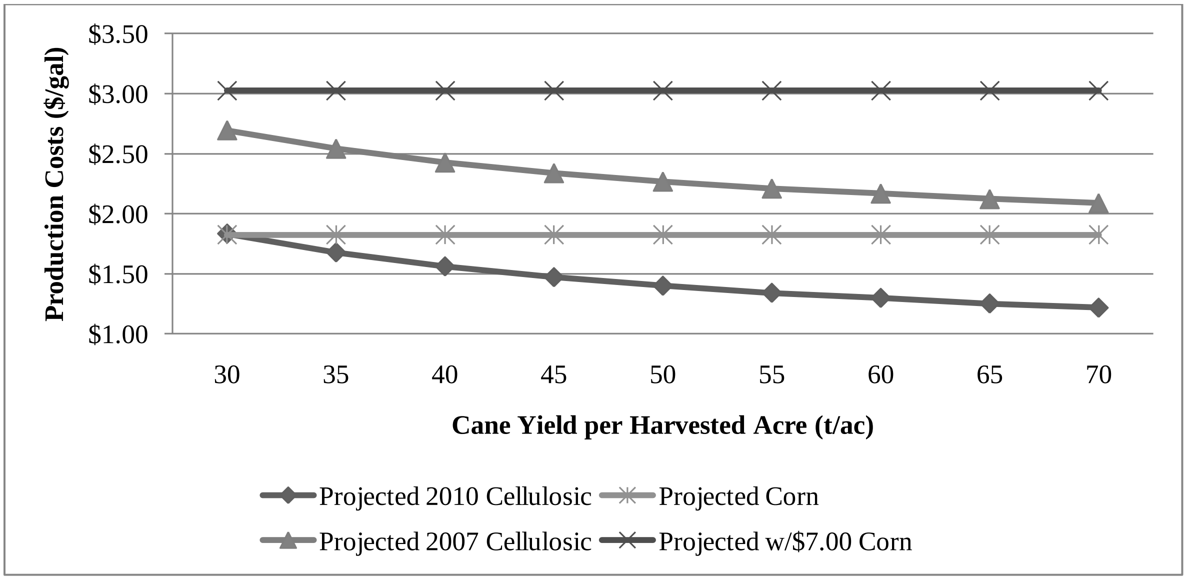
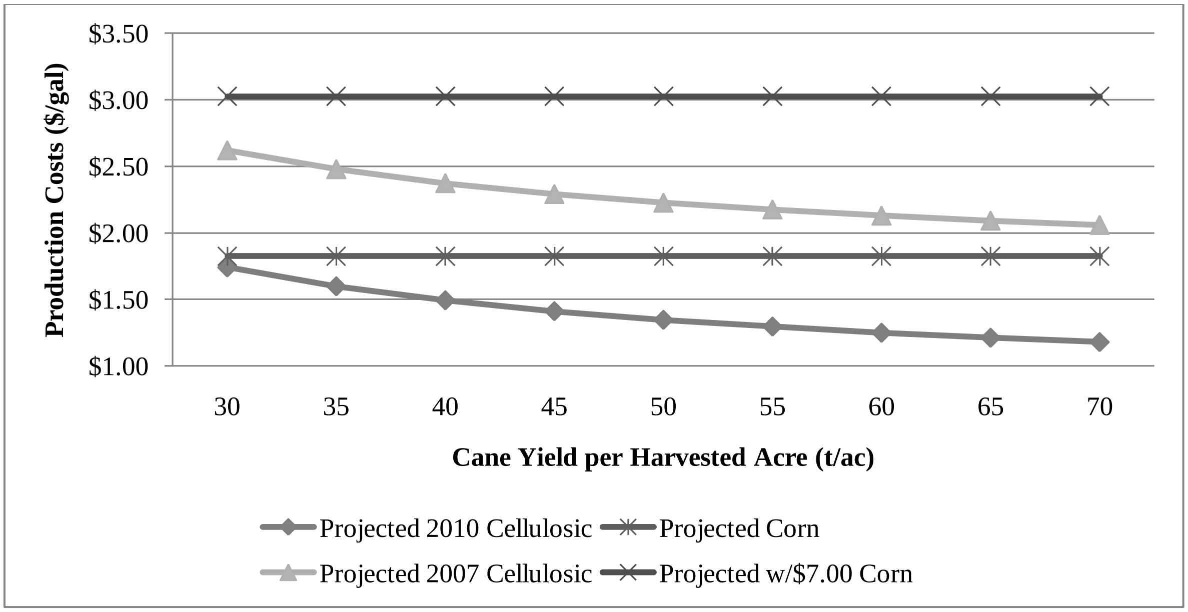
[7] This is assuming 30 t/ac and 25 gallons of ethanol per ton.

cane yields increase, it does approach traditional ethanol production cost and if energy cane yields reach 100 t/ac it becomes competitive with corn. Since 2007, the costs of enzymes have decreased by \$0.25 and as the 2010 line shows in both graphs cost of production for cellulosic ethanol is now below traditional ethanol. This is even true at today's energy cane yields and with minor yield improvements; production costs per gallon for cellulosic ethanol continue to fall. Furthermore, it is expected that capital costs could decrease as new production technologies are found. Increasing the value of byproducts (e.g. plastics, energy production, fertilizer, etc.) is another potential area where cellulosic ethanol can increase its competitiveness (Day, 2010). Figures 2.2 and 2.3 also present what happens to the cost of production when corn reaches \$7.00/bu as it did in 2007 (Projected w/corn \$7.00). When this happens, the production costs per gallon for traditional ethanol exceed \$3.00, assuming the processor purchases corn at the spot price (i.e., without contracts). In this environment, cellulosic ethanol has a lower cost of production relative to traditional ethanol for the processor.



*Assumes: \$3.70/bu corn; 24.98 gal/t ethanol

Figure 2.2: Comparison of Ethanol Production Costs Using Corn and Energy Cane (Harvest Through 3rd Stubble) Feedstocks



*Assumes: $3.70/bu corn; 24.98 gal/t ethanol

Figure 2.3: Comparison of Ethanol Production Costs Using Corn and Energy Cane (Harvest Through 4th Stubble) Feedstocks

Conclusions

For the renewable fuels supply chain to fulfill the mandated level of 36 billion gallons of biofuel production by 2022, other sources of feedstocks besides corn must be utilized. Although corn has dominated the ethanol industry historically, the other demands placed on corn stocks for feed grains, high fructose corn syrup, and exports means that the corn alone cannot meet this mandate. Cellulosic ethanol, a biofuel endorsed by EISA to meet this mandate, can be made from a wide variety of feedstock and the type of feedstock used is driven by location and resource endowments. In Louisiana, energy cane is one of the potential feedstocks that could be used.

Producers in Louisiana have not traditionally grown energy cane. However, its production similarities to sugarcane and the lack of other viable alternative crops make it an attractive option. The breakeven analysis conducted in this paper provides producers with a starting point to begin to analyze the decision of whether to grow energy cane, instead of sugarcane. For producers to switch, energy cane must provide them with at least the same expected net revenue on a per acre basis that they are receiving from sugarcane production. During the period 2005-2009, if producers could have secured contract prices at the breakeven prices, then they would have preferred growing energy cane, because expected net returns on per acres basis for the average sugarcane producers were less than estimated breakeven prices. Sugar prices in 2010, however, are above average.

To encourage farmers to produce energy cane, processors would likely have to provide prices above breakeven for energy cane. One option available to processors to decrease the required price for energy cane is to develop high yielding varieties. Increasing energy cane yield decreases the land requirements a potential cellulosic ethanol facility needs to operate at a minimum efficient scale. Furthermore, this measure should reduce the biomass transportation costs, as the processor would not have to contract with farms at longer distances. Another way to decrease the breakeven prices required by producers is to increase the stubbling lengths of energy cane varieties. Typically, sugarcane producers only harvest through second or third stubble, but if this could be increased to fourth or fifth stubble for energy cane, allowing producers to spread out the high establishment costs of the crop. The ability to increase stubbling length could be an advantage for energy cane. To increase the stubbling length, varieties with higher fiber content are needed and increased fiber content can lower the sugar content. Another reason that sugarcane producers like low fiber content sugarcanes is that it reduces repair and maintenance costs for both the producer and the mill.

Competitiveness of cellulosic ethanol with corn ethanol is also investigated in this study. Cellulosic ethanol production is competitive with corn ethanol at current energy cane yield levels and 2010 costs of production for cellulosic ethanol. Since 2007, enzyme costs for the lignicellulosic ethanol process have fallen by $0.25 and increased the competitiveness of cellulosic ethanol. The change suggests that cellulosic ethanol should be produced, relative to corn ethanol in those areas where significant biomass exists. Other factors that would help increase the competitiveness of the cellulosic ethanol industry include lower processing capital costs, market development of byproducts, and rising corn prices.

In summary, cellulosic ethanol could be a source of biofuels that could be used to help meet the RFS mandate for 2022. In Louisiana, energy cane has potential as a feedstock that could be converted into ethanol if it can be competitive with corn ethanol and the hurdle of scaling up to a commercial size is solved. In the short run, varietal enhancements with respect to yield and stubbling length are quickest and easiest ways to further increase competitiveness. Over time, as production costs continue to fall as they have done in the corn ethanol industry, cellulosic ethanol could be a key player in the biofuel debate.

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CHAPTER 3: A COMPARISON OF PRICING STRATEGIES FOR CELLULOSIC ETHANOL PROCESSORS: A SIMULATION APPROACH

Introduction

The 2005 Energy Policy Act established a Renewable Fuel Standard (RFS), mandating 4.0 billion gallons of biofuels be produced annually by 2006, with that goal rising to 7.5 billion gallons annually by 2012 (Tyner, 2007). Since both of these mandated levels were surpassed before their deadline, a new RFS was passed in 2007 with the ratification of the Energy Independence and Security Act (EISA), which mandates that fuel producers use at least 36 billion gallons of biofuels by 2022 (OPS, 2007). EISA also places an emphasis on the production of cellulosic ethanol. Of the 36 billion gallons, 16 billion gallons are expected to be produced via “cellulosic ethanol.” To reach these mandated levels of biofuel production will require the production of a variety of energy crops, and the farm location will likely govern the energy crop produced.

Louisiana’s subtropical climate makes it an advantageous location for the production of biomass. The state lies between the 29th and 33rd parallels north of the equator, has an average yearly temperature of 66 degrees, an average precipitation of 64 inches per year, and a range of 230 to 290 growing days in the southern part (i.e. south of Alexandria) of the state (LOSC, 2009). These conditions make energy cane, a crop similar to sugarcane, the most viable biomass crop for Southern Louisiana. Energy cane is lower in sucrose or brix content, but higher in fiber content than traditional sugarcanes varieties (e.g., LCP85-384). In 2000, sugarcane acres in Louisiana peaked at 465,000, but since have been decreasing an average of one percent per year (USDA, 2010a). This decrease in acreage likely stems from Louisiana producers searching for alternative crops to grow because prices have been low. Until now, no viable crop alternatives have surfaced in the sugarcane belt (Figure 3.1). The emergence of crops used for the production of sustainable energy could provide viable alternatives for producers in the Sugarcane Belt.

Figure 3.1: Louisiana Sugarcane Belt

In 2007, the Louisiana Agricultural Experiment Station, in conjunction with the American Sugar Cane League and the United States Department of Agriculture, released three energy cane (high fiber cane) varieties: L79-1002, Ho 00-961, and HoCP 91-552 (ASCL, 2007). L 79-1002 yield have been reported in excess of 100 t/ac, significantly higher than current sugarcane yields of 30 t/ac. However, there is no research plot data to substantiate these potential yield levels.

Before energy crop production takes place, processors must determine how they are going to price the biomass produced by these crops. Iogen, a cellulosic ethanol producer, uses wheat, oats, and barley in the production of cellulosic ethanol. The company is looking to expand into the Pacific Northwest region of the United States (Iogen, 2010). Iogen has given potential producers the opportunity to choose between two different production contracts with lengths of five or six years (Altman et al., 2007). The first contract type is a fixed pricing option, which provides producers approximately $10 per ton of straw in the field. Producers can also choose a variable pricing contract, which provides a price per ton of straw between $7 and $15. The price received is dependent on the price of oil (Pratt, 2005). The idea behind the variable pricing option is to allow producers to manage input risks better, since fuel and fertilizer costs typically move with crude oil prices. Harvest and delivery of the straw from the field to the processing plant are handled by a separate contract between Iogen and a custom harvester (Pratt, 2005).

Zahn et al. (2005) examined two different procurement-pricing strategies for switchgrass in Alabama. The first, a fixed pricing strategy implies that one uniform price is paid to biomass producers regardless of transportation costs. The advantages of this type of pricing strategy are the simplicity of implementation and the avoidance of potential transportation-related disputes. The downside, however, is the potential for high delivered raw material costs because the marginal price is fixed.

Secondly, a discriminatory strategy is one where the price will be source-specific and based on the farm-gate price and the cost of transportation to the processor. The advantage of a discriminatory type of pricing strategy is that once the demand level is high enough, the procurement cost savings for this strategy exceed the additional administration costs incurred. One downside to this strategy is that it requires additional workers to do the site-specific pricing.

Zahn et al. (2005) find spatial variation plays a role in the procurement costs for both pricing strategies and that the fixed pricing strategy always costs more than the discriminatory strategy for the processor. Additionally, they were able to find a breakeven point of the two strategies for processors that have a demand that exceeds 300,000 tons, the proper strategy to employ is a discriminatory strategy.

A key shortcoming of both Altman et al. (2007) and Zahn et al. (2005) is that neither investigates how the potential biomass producers' expected net revenue is impacted. My study examines four different pricing strategies to determine, from the producer's perspective, the strategy that provides the highest expected net returns per acre relative to sugarcane production. For this study, potential profit margins for the biofuel processing firm are not investigated due to the lack of sufficient data. However, examining this from the producers' perspective allows potential biomass processors to discover a range of what they might have to pay producers per ton of biomass to elicit feedstock into production.

Assuming that producers operate as profit maximizing firms, then for new crops to come into production in the Sugarcane Belt, they must provide producers with at least the same expected net returns per acre as sugarcane (Nicholson, 2004). Without this equivalent return criterion being achieved, there is no incentive for producers' to adopt the production of energy cane in the Sugarcane Belt. This will be a key hurdle for the adoption of any energy crop, no matter the location of its production.

Unlike the well-developed, conventional corn-to-ethanol supply chain, the biomass supply chain for cellulosic ethanol still has significant hurdles to overcome. Identifying pricing strategies for biomass is critical for the development of the cellulosic ethanol industry's supply chain. Altman et al. (2007) point out that the current *ad hoc* supply chain of informal contracts and even bartering needs to become more formalized for large-scale processors to profit. In conjunction with the nontraditional nature of energy crops, the infant-stage status of the industry has left many agribusinesses and producers wondering how to price these nontraditional energy feedstocks.

The first objective this paper is the implementation of a simulation model that compares different pricing strategies. This model is used to forecast producers' expected net returns over the time for 2011 to 2015. The second objective is to rank the pricing strategies based on the risk preferences of the potential producers. These pricing strategies are ranked using Stochastic Dominance (SD) and Stochastic Efficiency with Respect to a Function (SERF) (Richardson et al., 2008). The third objective uses sensitivity analysis to investigate and determine key input variables for these strategies.

Literature Review

Simulation

Simulation is a popular analytical tool. It is used in agriculture to analyze farm programs, risk management strategies at the farm and agribusiness levels, and agricultural policy. Simulation allows for market reproduction under certain conditions or events that are likely to occur in the future (Agrawal and Heady, 1972). Since the data on potential energy crop yields and pricing strategies that cellulosic ethanol processors might employ is limited at best, simulation allows for the investigation of several different pricing scenarios that producers in the Sugarcane Belt could be confronted with in the coming years as cellulosic ethanol production is commercialized.

According to Richardson et al. (2000), there are several unique aspects that should be considered when developing an agricultural farm-level simulation model: 1) non-normally distributed random yields and prices, 2) intra-temporal correlation of production across enterprises and fields, 3) intra- and inter-temporal correlation of output prices, 4) heteroskedasticity of random variables over time due to policy changes, 5) numerous enterprises that are affected by weather and carried out over the growing season, 6) government policies that effect price distributions, and 7) strategic risks with technology adoption and contract negations.

Numerous other studies “see footnote” have investigated the normality of crop yields and/or correlation between crop yields and price using both parametric and nonparametric approaches.[8] Featherstone and Kastens (2000) and Hogg and Craig (1963) point out that nonparametric methods are distribution-free and might result in increased model accuracy because they are not susceptible to model specification error. Ramirez et al. (2003), however, suggest that nonparametric methods can be problematic in small samples, while parametric methods, even if they are susceptible to misspecification, work well in small samples that are typically seen in agricultural economics.

In general, though, there is no consensus with either nonparametric or parametric methods as to which direction crop yields are skewed. Day (1965) found that crop yields were positively skewed. Gallagher (1987), Swinton and King (1991), and Rameriz (1997) found crop yields to be negatively skewed. Just and Weninger (1999) point out that testing for normality in crop yields is difficult because of the complex behavioral, physical, biological, economic and sociological processes, when the specifications for each of these are unknown. Furthermore, correlating these non-normally distributed crop yields both inter- and intra-temporally, is key, as shown by Richardson et al. (2000). They find that not performing both correlations results in less variability of the joint distributions and could substantially influence the policy implications of the model.

Given that, the normality of crop yields and prices is difficult to assess, parametric methods impose distributional assumptions, and that correlation among yields and prices need to be considered. A multivariate empirical distribution (MVE) is used, as described by Richardson

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[8] Ramirez et al., 2003; Featherstone and Kastens, 2000; Ramirez, 2000; Just and Weninger, 1999; Goodwin and Ker, 1998; Ramirez, 1997; Ramirez et. al, 1994; Swinton and King, 1991; Taylor, 1990; Nelson and Preckel, 1989; Gallagher, 1987; Richardson and Condra, 1978; Clements et al., 1971; and Day, 1965

et al. (2000), and therefore does not impose any distributional assumptions on the sample. Since the MVE is a nonparametric distribution, it allows for the issue of non-normality to be addressed. It also allows for multiple crop enterprises across an operation to be both inter- and intra-temporally, correlated allowing for the full characterization of risk (Richardson et al., 2000).

Ranking of Pricing Strategies

The ability to rank the different pricing strategies is pivotal in helping to determine the preferred strategy from the producer's perspective. Methods include: mean only, standard deviation, mean-variance, worst and best case, relative risk, probabilities of target values, complete distribution, SERF, SD, and certainty equivalents (Richardson et al., 2008). Richardson et al., 2008 provide an in-depth discussion of each of these, but for the purposes of this study, SD and SERF are used because they are the two most comprehensive methods for ranking these strategies.

The use of first-order SD allows all simulated observations to be employed. The method also allows for comparisons for both risk-neutral and risk-averse decision makers (Richardson, 2008). Furthermore, SD allows for the ranking of strategies when the preferences of the decision maker are not known (Chavas, 2004). This method determines under which conditions one strategy will dominate all others. SERF is employed to examine how the preferred strategy changes over the risk spectrum.

Hardaker et al. (1997) suggest that individuals can be characterized by their risk aversion coefficient (RAC). RACs typically range from risk-neutral (RAC=0) to extremely risk-averse (RAC=4). The use of SERF creates an opportunity for the ranking of risky alternatives over the above range of RACs. The SERF method also allows for different types of utility functions (e.g., negative exponential, power utility, quadratic, etc.) to be analyzed. For the purposes of this study, a negative exponential utility function is used to analyze the pricing strategies.

Negative exponential utility functions have been widely used in the agricultural economics literature (Watkins et al, 2008; Hardaker et al., 2004; Kebede et al. 1990). One of the limiting assumptions of this utility function is its assumption of constant absolute risk aversion (CARA), which implies that increases in wealth do not affect the level of risk the producer is willing to assume (Hardaker et al, 1997 and Chavas, 2004). In some cases, this may be an undesirable property. According to Tsiang (1972), however, the use of this functional form is acceptable when the risky alternatives being examined are small relative to decision makers' wealth. Furthermore, McCarl (1990) found that CARA functional forms display the same results as alternative functional forms over small intervals.

Methodology and Data

A theoretical discussion and the steps involved in the estimation of an MVE distribution can be found in Richardson et al, 2000.[9] Table 3.1 contains sources for the data used in this analysis and their summary statistics. The MVE model contains historical data (2000-2009) on sugarcane yields, raw sugar prices, and commercially recoverable sugar (CRS), all of which has been detrended. Using the MVE distribution, random deviates are extracted from the historical data. These deviates are then used to forecast yields for both sugarcane and energy cane for the 2011 to 2015. The random deviates for sugarcane yields are then used in an ordinary least squares model to forecast sugarcane and energy cane yields for 2010-2015. Since sugarcane and energy cane come from the same genus, they are assumed to have the same distribution of random deviates.

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[9] For a detailed example, see Richardson et al, 2000.

Table 3.1: Variable Summary Statistics and Sources, 2000-2009

Variable	Units	Mean	Stdev	Max	Min	Source
Historical Sugar Price (Raw)	cents/lb	21.36	1.48	24.93	19.09	USDA, 2010b
Historical Sugarcane Yield	t/ac	28	2.69	31	23	USDA, 2010a
Forecasted Sugarcane Price	cents/lb	25.66	1.84	29.36	24.54	FAPRI, 2010
Historical Commercially Recoverable Sugar	lb/ac	209.1	13.78	229	179	ASCL, 2010
Historical Sugarcane Production Costs less harvest	\$/ac	487	37.63	529	425	Salassi and Deliberto, 2010
Historical Sugarcane Harvest costs	\$/t	3.05	0.24	3.31	2.59	Salassi and Deliberto, 2010
Historical Crude Oil Price	\$/barrel	46.35	23.05	92.33	21.99	EIA, 2010
Historical Ethanol price	\$/gal	1.79	0.50	2.58	1.12	NEB, 2010
Forecasted Ethanol Price	\$/gal	2.47	0.26	2.70	2.07	EIA, 2010
Historical Corn Price	\$/bu	2.63	1.011	4.78	1.78	FAPRI, 2010
Forecasted Corn Price	\$/bu	3.85	0.08	3.96	3.72	FAPRI, 2010
Historical Natural Gas Prices	\$/1000ft^3	6.52	1.87	9.67	4.02	EIA, 2010
Forecasted Natural Gas Prices	\$/1000ft^3	6.54	0.35	6.88	6.05	EIA, 2010

Sugarcane (*sugyld)* and energy cane (*ecaneyld)* yields are forecasted using a simple ordinary least squares (OLS) regression, as shown in Equations 3.1 and 3.2. These equations are a function of lagged yields ($sugyld_{t-1}$ and $ecaneyld_{t-1}$). As proxy for nitrogen fertilizer costs the price of industrial natural gas (*natgas*), time (*t*), and the random deviate (*rd*) are generated by the MVE. Natural gas is the primary input in the production of nitrogen fertilizer and tends to be a good predictor of nitrogen price (GAO, 2003). These random deviates allow for stochastic sugarcane and energy cane yield to be produced in the simulation model.

$$sugyld_t = f(sugyld_{t-1}, natgas_t, t, rd) \tag{3.1}$$

$$ecaneyld_t = f(ecaneyld_{t-1}, natgas_t, t, rd) \tag{3.2}$$

Sugarcane and energy cane yields are measured in tons per acre (t/ac), natural gas prices are in \$/1,000ft^3 (nominal), time is in years, and *rd* is the random deviate in t/acre. The difference between these two equations is that energy cane yields are expected to be higher than traditional sugarcane yields. Consequently, they have been adjusted upward over the period 2000-2009, to an average energy cane yield of 35 t/acre. In contrast, traditional sugarcane varieties during this time period have averaged only 30 t/acre (USDA, 2010a). Using this information, we can carry out the calculations for the different pricing strategies.

Table 3.2: OLS Regression for Sugarcane Yield

Variable	**Coefficient**	**Standard Errors**
Intercept	18.345*	8.449
sugyld$_{t-1}$	0.455	0.265
natgas$_t$	-0.984*	0.505
t	0.407	0.266
N	13	
R^2	0.535	

*Significant at the 10% level

Table 3.3: OLS Regression for Energy Cane Yield

Variable	**Coefficient**	**Standard Errors**
Intercept	19.875*	9.154
ecaneyld$_{t-1}$	0.455	0.265
natgas$_t$	-1.067*	0.547
t	0.441	0.288
N	13	
R^2	0.535	

*Significant at the 10% level

Regression results for sugarcane and energy cane yields are shown in Tables 3.2 and 3.3. Both regressions exhibited the expected signs for independent variables. Specifically, natural gas, the proxy for nitrogen fertilizer, has a negative sign and is significant at the 10% level. This implies that as natural gas prices increase (nitrogen fertilizer prices follow), producers will purchase less fertilizer, in turn decreasing expected yield. The R-squared value for both of these regression equations is approximately 53.5%. The rationale behind both equations having the same R-squared is that energy cane yields rely on sugarcane yields but are adjusted upward to reflect that they are higher yielding. Otherwise, sugarcane and energy cane are similar plants coming from the same genus.

Following the discussion by Altman et al. (2007) of pricing strategies being considered by Iogen for pricing biomass, this research formulates four potential biomass pricing strategies. While numerous pricing strategies could have been examined, the four presented here are broken down into two different categories: 1) variable and 2) hybrid. There are three different variable pricing strategies, which use feedstock procurements as a percentage of lignocellulosic ethanol production costs to determine biomass price based upon forecasted ethanol, corn, and crude price for 2011 to 2015. A general description price determination of the variable strategies is shown in Equation 3.3,

$$price_i = (eqv_i / tonperac) * feed\%, \tag{3.3}$$

where *price* is the biomass price (\$/t), *eqv* is an equating factor, *tonperac* is the tons of energy cane produced per acre, *feed%* is the feedstock procurement cost percentage, and *i* is pricing strategy.[10]

A key factor in this equation is the feedstock procurement cost percentage. Feedstock percentage is the portion of a gallon of cellulosic production cost that feedstock purchasing is accountable. As a starting point in the analysis, Collins (2007) estimated that feedstock procurement accounts for 46% of cellulosic ethanol production costs. Furthermore, the variable pricing strategies are premised on the idea that in recent years there has been a strong, positive correlation between corn, ethanol, and crude oil prices (Wagner, 2009). The expectation is that the variable pricing strategies will not induce the production of energy crops at a feedstock procurement percentage of 46%. As this percentage increases, however, the above strategies will

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[10] In general, this equating factor is used to equate costs from ethanol, corn, and crude oil to energy cane. This equating factor is discussed for each pricing strategies below and dependent upon the strategy it changes.

offer producers the potential for larger expected net returns per acre relative to the hybrid strategy.

The fourth pricing strategy is a hybrid, with the first component being a guaranteed percentage of energy cane production costs and the second a fixed dollar amount per ton component based upon realized energy cane yield. The strategy is adapted from a study by Morris et al. (2009), which examined the usage of sweet sorghum juice for the fermentation of ethanol. The first component of this strategy stipulates the producer receive a fixed percentage of their production costs; the initial model assumes producers receive 90% of variable production costs. The second component of this strategy provides producers with a flat $13.00 per realized ton of biomass production. This combination of pricing components is selected because it provides producers with similar expected net revenues per acre to that of sugarcane. The expectation is that this strategy will induce the production energy crops because it provides producers with downside risk protection through the guaranteed portion. These strategies are then compared to the expected net returns for sugarcane production in the Louisiana Sugarcane Belt. In a deterministic setting, the price paid to producers is shown in Equations 3.4 through 3.9.

To determine the price per ton of energy cane a producer will receive under a variable ethanol pricing strategy, Equation 3.4 is used:

$$prodeth = ((tethp * galperac)/tonperac) * feed\%, \qquad (3.4)$$

where *prodeth* is the biomass price ($/t) paid to producers, *galperac* is gal/acre of ethanol production, *feed%* is feedstock's portion of the cost of production, *tethp* is ethanol price in $/gal, and *tonperac* is the tons of energy cane produced per acre. Gallons of ethanol per acre are calculated by assuming average energy cane yields are 35 tons per acre (*tonperac*) and a lignocellulosic ethanol plant can produce 24.58 gal/t of biomass. As a starting point, *feed%* is assumed to be 46%, in accordance with Collins (2007). The last component needed to determine the producers' price is a forecast of ethanol price (*tethp*). Ethanol price forecasts are taken from the 2010 FAPRI Baseline. This forecast provides the mean to be used in a Gray-Richardson-Klose-Schumann (GRKS) distribution. The distribution is a variation of the triangle distribution that allows for sampling outside of the minimum and maximum values 2.2% of the time (Richardson et al., 2008). Other characteristics of the distribution are the existence of four equal distance intervals exist between the minimum (maximum) and midpoint, two intervals above and below the minimum and maximum, and 50% of the simulated observations are less than the midpoint (Richardson et al., 2008). Minimum and maximum values are extracted from the 2000-2009 ethanol price history.

Equation 3.5 is used to determine the price per ton of energy cane (*prodcorn*) delivered to the processor under a variable corn pricing strategy,

$$prodcorn = \Big(\big((galperac/ethperbu) * tcornp\big)/tonperac\Big) * feed\%, \tag{3.5}$$

where *galperac* is 35 t/ac, *ethperbu* represents the 2.8 gallons of ethanol produced per bushel of corn, *tonperac* is stochastic energy cane yield per acre, *feed%* is 46% of the production, and corn price (*tcornp*) is the forecasted $/bu for corn in 2010-2015 (Schnitkey et al., 2007). The mean corn price is extracted from 2010 FAPRI Baseline and used in the GRKs distribution.

Equation 3.6 shows the calculations for the crude oil pricing strategy. Given the complexity of the crude oil market and the many international factors involve in predicting crude oil price (*tcrudep*), EIA (2010) projections were used. Each barrel of crude oil (*crudebarrel*) contains 42 gallons. Equation 3.6 describes how price paid to producers (*prodcrude*) varies under a crude oil variable strategy:

$$prodcrude = \Big(\big((galperac/crudebarrel) * tcrudep\big)/tonperac\Big) * feed\%, \tag{3.6}$$

where *prodcrude* is the $/t producers receive for energy cane, *tcrudep* is dollar per barrel for crude oil, *tonperac* is a stochastic energy cane yield, and *feed%* represents 46%. Again, forecasted prices are taken from the FAPRI Baseline and a GRKs distribution is employed using historical minimums and maximums.

The fourth hybrid pricing strategy is a two-tiered approach that contains a guaranteed and variable component. Equation 3.7 shows how the hybrid producer (*prodhybrid*) price is determined:

$$prodhybrid = ttotcost * guarantee + tonperac * real, \tag{3.7}$$

where cost of production less harvest costs (*ttotcost*) is in $/ac, *guarantee* is 90% of the production cost guaranteed by the processor plus a fixed price (*real*) from the processor for each realized ton of production per acre of energy cane *tonperac*.

The sugarcane pricing strategy functions as a barometer for the other strategies. If the previously discussed strategies do not provide higher expected net returns than this strategy, then producers have no incentive to produce energy cane. Sugarcane yields (*sugyld*) and *CRS* are computed using the MVE. Sugar price (*sugp*) forecasts are extracted from 2010 FAPRI Baseline and a GRKs distribution is employed. Equation 3.8 shows how the producers' (*prodsug*) price in this strategy is constructed.

$$prodsug = sugyld * sugp * crs \tag{3.8}$$

The second component needed to calculate expected net returns per acre is cost of production forecasts for 2011 to 2015. Cost information for sugarcane production is obtained from the previous six years of sugarcane budgets. The budgets are broken down into total costs and variable costs of production. Total cost of production is the sum of fixed, variable, and overhead costs minus the $/t harvest costs. Variable cost is total cost minus fixed, overhead, and harvest costs. A differentiation is made between these two types of costs because annual sugarcane budgets assume that new equipment is being used. Consequently, using total costs can understate the expected net returns for a crop. Harvest costs are separated to account for the potential for increasing energy cane yields.

Now that the producers' price per ton for each of the strategies has been determined, revenue per acre can be ascertained for each strategy by multiplying each of the producer prices by the realized tons of energy cane produced per acre. The price per ton is multiplied by 80% to account for the fact that in a 1,000-acre representative farm, one-fifth of each acre is always fallow, due to the perennial nature of sugarcane and energy cane. With total revenue computed, the cost of production can be subtracted to compute expected net revenue (profit) per acre under each of the different strategies.

Ranking of Pricing Strategies

To allow for the comparison of expected net returns, the returns are discounted back to the present value. Two different discount rates are used to establish upper and lower bounds. The upper bound is established using the bond market average return of 4.7% from 1879 to 2009 (Shiller, 2010). The lower bound on expected net returns is established using the stock market average return of 8.5% from 1879 to 2009 (Shiller, 2010).

Through the SD and SERF functions in SIMETAR, 10,000 iterations for each of the pricing strategies are computed. SD is used initially to determine first and second order stochastic dominance for the strategies. Then SERF is used to investigate different scenarios when there is no first or second orders stochastic dominance. For the SERF function, as stated earlier, a negative exponential utility function is selected. To utilize negative exponential utility function, RACs need to be transformed into absolute risk aversion coefficients (ARACs). This is accomplished by using the expected net return from sugarcane and dividing it by four. Given that sugarcane is the crop currently being produced, it is logical that expected net revenue from sugarcane should be used in this transformation. Using SERF, pricing strategies are ranked for 2011 and 2015 to determine if the preferred strategy for producers changes overtime. SERF is also used to evaluate the preferred strategy over the time of 2011 to 2015 by summing up the NPV of each strategy.

Sensitivity Analysis

Two different key variables are analyzed so that their impact on expected net returns can be investigated. For the variable pricing strategies, the key variable analyzed is the percentage of cellulosic ethanol production cost that feedstock procurement contributes. In the hybrid pricing strategy, the key variable examined is the producers' guaranteed percentage of production costs. For purposes of this study, feedstock share is examined at the initial level of 46%, with a decrease of 5% and increases of 5, 20, and 50%, respectively. It is expected that as cellulosic ethanol technology matures, the feedstock share of cellulosic ethanol production costs will increase just as it has in the traditional corn ethanol industry. Currently, feedstock costs for the traditional ethanol industry represent approximately 70% of the total cost of production (Collins, 2007). As for the hybrid pricing strategy, the initial 90% of production cost is examined, along with a 5% increase, and 5, 10, and 15% decreases, respectively. Our a priori expectations are that as the industry matures, processors may want to eliminate this type of strategy.

Results

In general, the results for the pricing strategies confirm a priori expectations that no pricing strategy currently induces the production of energy cane in the Sugarcane Belt. Over the period 2011 to 2015, the hybrid pricing strategy provides producers with the highest expected net returns of the four strategies investigated. The sensitivity analysis shows that corn and crude oil require significant increases in the feedstock share, but for the ethanol and hybrid pricing strategies only small changes are required to induce production.

The results section is broken down as follows. First, the results are discussed assuming that producers must cover the total cost of production for energy cane. One caveat of this assumption is that total costs include the fixed costs, which are based on purchase prices of new equipment. Although this equipment cost estimation procedure will somewhat overestimate fixed costs, it does incorporate the assumption that producers at some point must replace equipment for their operation to remain economically viable. With this in mind, I use the second portion to examine a producer's expected net returns when they are only covering the variable cost of production. To allow for comparison, all results are discounted back 2010. The results are the same regardless of the discount rate chosen, with the only difference between the two is that lowering the discount rate results in higher expected net returns per acre.

Producer Expected Net Returns When Covering Total Costs of Production

In the long run, producers considering energy cane must cover the total cost of production. Table 3.4 shows the frequency with which producers exceed the total cost of production for the different pricing strategies. It is expected during the period 2011 to 2015 that sugarcane producers will exceed their total cost of production between 99% and 97% of the time for 2011 and 2015, respectively. The probability of exceeding total cost decreases in 2014 and 2015, as sugar prices are forecasted to decrease while production costs increase. For the four pricing strategies investigated, the hybrid pricing strategy is the only one that provides a producer with a higher probability of exceeding their total cost of production. Corn and crude oil pricing strategies perform poorly, though crude oil does improve as forecasted prices increase over the same period.

Table 3.4: Percentage of the Time a Producer is Above Breakeven for Each Strategy

	Year				
	2011	**2012**	**2013**	**2014**	**2015**
Sugar	99%	99%	98%	97%	97%
Pricing Strategies for Energy Cane					
Ethanol	74%	73%	74%	71%	72%
Corn	4%	3%	3%	2%	2%
Crude	19%	18%	20%	20%	21%
Hybrid	100%	100%	100%	100%	100%

Table 3.5 shows the results for the 10,000 iterations of the model for 2011. For 2011, no pricing strategy evaluated has a higher expected net return than sugar, implying there is no incentive for risk neutral producers to consider energy cane production. This is consistent with expectations, as there is no energy cane being produced to date in the Sugarcane Belt. Additionally, the hybrid pricing strategy provides producers with $217 per acre, which is the highest expected net return of the four pricing strategies examined and conforms to current expectations. This is on average $35 per acre less than the expected net return of a sugarcane producer. On a per acre basis, the figure may not seem significant. However, on a 1,000 acre farm, the profits amount to approximately $35,000 in net farm income.

An ethanol pricing strategy provides producers with the second highest expected net return of $70 per acre, which is on average $182 less per acre than sugarcane. However, corn and crude oil pricing strategies defy expectations and provide producers on average a negative $180 and $106 per acre, respectively. Using the current assumptions, a producer choosing to produce energy cane under one of these strategies would be eroding the value of their operation. From a producer's standpoint; these two pricing strategies should not even be considered unless significant changes are made to them.

Table 3.5: Results for Pricing Strategies for Total Costs of Production, 2011

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$251.92	$103.02	41	-$104.22	$625.64	$53.56	$456.44
				Pricing Strategies for Energy Cane			
Ethanol	$70.12	$102.36	146	-$236.12	$585.51	-$111.38	$292.46
Corn	-$180.38	$90.96	n/a	-$437.84	$260.42	-$329.95	$26.85
Crude	-$106.35	$123.11	n/a	-$515.36	$448.24	-$311.24	$171.43
Hybrid	$217.04	$19.00	9	$164.09	$253.56	$179.06	$242.84

*n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

A unique feature of the hybrid pricing strategy is that it provides producers with downside risk protection through the guaranteed percentage of cost of production. As a result, it has the lowest coefficient of variation and 95% of the observations are between $179 and $243 per acre (Table 3.5). Relative to sugar, which has a higher coefficient of variation and a larger confidence interval of $54 to $456, the hybrid strategy provides producers with a less variable net return. A disadvantage of the strategy is that it slows a producer’s ability to respond to increases in input costs. Since the guaranteed portion is based on historical production costs of the region, it takes time for the increased input cost to be reflected in regional production costs.

Table 3.6: Results for Pricing Strategies for Total Costs of Production, 2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$165	$87	52	-$214	$495	-$9	$328
				Pricing Strategies for Energy Cane			
Ethanol	$52	$86	164	-$266	$391	-$111	$228
Corn	-$155	$73	n/a	-$409	$159	-$293	-$3
Crude	-$77	$98	n/a	-$453	$314	-$259	$127
Hybrid	$160	$14	9	$117	$195	$131	$181

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

Table 3.6 shows the results for 10,000 iterations of expected net returns in 2015, discounted back to 2010. In 2015, a strategy has yet to be found that will induce the production of energy cane over sugarcane based on average expected net return. However, the hybrid pricing strategy has closed the gap between energy cane and sugarcane to $5 per acre. The hybrid pricing strategy has been able to close this gap as forecasted sugar prices decrease over the period 2011 to 2015. Corn and crude oil pricing strategies still perform poorly and require significant changes before they can become viable strategies for processors.

Table 3.7: Results for Pricing Strategies for Total Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$855	$181	21	$133	$1,552	$500	$1,210
Pricing Strategies for Energy Cane							
Ethanol	$250	$180	72	-$402	$1,014	-$93	$608
Corn	-$714	$156	n/a	-$1,266	-$52	-$1,008	-$392
Crude	-$388	$207	n/a	-$1,024	$386	-$777	$30
Hybrid	$788	$31	4	$668	$872	$724	$844

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

The hybrid pricing strategy provides producers on average with lower expected net returns per acre compared to sugar. However, for producers preferring lower variability in expected net returns the strategy could be a viable one if a producer is willing to trade higher expected net returns for lower variability. Other desirable qualities of the hybrid pricing strategy are that it has the lowest coefficient of variation out of all the strategies, covers the total costs 100 percent of the time, and over 10,000 iterations has a minimum expected net return of $117. Compared to the other pricing strategies this is an advantage of the hybrid pricing strategy because all other strategies have the potential for negative expected net returns. To determine if any of the potential pricing strategies over the period from 2011 to 2015 provide a producer with higher expected net returns than sugarcane production, the discounted expected net returns for each year are summarized in table 3.7. As expected, none of the strategies outperformed sugarcane production; consequently, risk neutral producers over this period prefer sugarcane production because it has an expected net return of $855 per acre, $67 higher than that of the hybrid pricing strategy.

Some producers prefer lower variability in their expected net returns per acre. As producers become more risk averse, they prefer strategies that have less variability in expected net returns per acre. The hybrid strategy becomes an attractive option to such producers by having the smallest standard deviation of $31 per acre, with 95% of expected net returns falling between $724 and $844 per acre. The hybrid strategy, operating as designed, provides producers decreased downside price risk protection, but producers must also realize that the strategy decreases their earning potential. Comparatively, sugar has a standard deviation of $181 per acre and 95% of the observations are between $500 and $1,210. Ethanol has the third highest discounted expected net return per acre of $250, followed by crude and then corn. Corn exhibited the lowest discounted expected net return per acre of -$714. Furthermore, the maximum value observed in the simulation was -$52. A processor offering this type of corn pricing strategy would not induce the production of energy cane, unless significant changes were made to it or an additional fixed component was added.

Sensitivity Analysis

For a processor to induce the production energy cane by a risk neutral producer in the Sugarcane Belt, changes are required to make energy cane pricing strategies viable. Table 3.8 contains the sensitivity analysis for the three variable strategies. For each strategy, 2.3, -2.3, 9.2, and 23 percentage point changes or shares of 48.3%, 55.2%, 69%, and 43.7%, respectively are examined. This variable is set initially at 46%, but over time, it is expected that feedstock share of costs will increase as other costs associated with the production process decrease.

Table 3.8: Results for Variable Pricing Strategies Sensitivity for Total Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$855	$181	21	$133	$1,552	$500	$1,210
			Pricing Strategies for Energy Cane				
Ethanol							
Initial	$250	$180	72	-$402	$1,014	-$93	$608
5% decrease	$142	$173	122	-$477	$817	-$190	$493
5% increase	$357	$188	53	-$316	$1,093	-$2	$738
20% increase	$680	$209	31	-$74	$1,506	$280	$1,108
50% increase	$1,326	$255	19	$409	$2,334	$842	$1,848
Corn							
Initial	-$714	$156	n/a	-$1,266	-$52	-$1,008	-$392
5% decrease	-$774	$150	n/a	-$1,306	-$144	-$1,059	-$474
5% increase	-$655	$161	n/a	-$1,203	$25	-$960	-$331
20% increase	-$477	$178	n/a	-$1,047	$279	-$812	-$115
50% increase	-$121	$214	n/a	-$783	$787	-$516	$321
Crude							
Initial	-$388	$207	n/a	-$1,024	$386	-$777	$30
5% decrease	-$464	$199	n/a	-$1,110	$317	-$837	-$61
5% increase	-$313	$216	n/a	-$1,020	$547	-$717	$128
20% increase	-$86	$243	n/a	-$886	$892	-$536	$412
50% increase	$369	$298	81	-$617	$1,582	-$184	$980

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

An ethanol pricing strategy assuming a 46% feedstock share would not induce energy cane production, represented by initial in Table 3.8. If processors increased the feedstock share by 9.2 percentage points, producers' expected net returns increases to $680 per acre, which is on average $175 per acre less than those of sugarcane producers over the period 2011 to 2015. For an ethanol pricing strategy to become a viable option producers need the feedstock share of cost of production to increase it by 12.9 percentage points The corn pricing strategy as it is currently constructed will not be viable even if the processor increased the feedstock share to 100%. This is not possible, and if a processor desires to use a corn strategy it will have to include additional components (e.g., per ton guarantee, subsidized seed costs, etc.). For the crude oil pricing strategy, more than a 23 percentage point increase in feedstock share is required for this strategy to induce energy cane production. At a feedstock share of 84%, crude oil provides producers with expected net returns equivalent to that of sugar. However, this is 12 percentage points above where the corn ethanol industry is operating; it is unexpected that this would be feasible.

The hybrid pricing strategy had the highest expected net returns of the strategies investigated as shown above, but it still fails to induce the production of energy cane. A key driver for the hybrid strategy is the guaranteed percentage of the production costs. Table 3.9 contains the results for 5, 10, and 15% decreases in this variable. A 5% increase in this variable is also examined. Over time, the expectation is that processors will not want to continue paying this guaranteed portion to producers after the industry begins to mature. Until this happens, however, processors may have to increase the guaranteed portion by 4.5 percentage points to a 94.5% guarantee to induce production. At this level, the hybrid strategy has an average expected net return of $860 per acre. This is on average $5 per acre higher than sugarcane, which may make producers indifferent between the production of sugarcane and energy cane.

Table 3.9: Results for Hybrid Pricing Strategies Sensitivity for Total Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$855	$181	21	$133	$1,552	$500	$1,210
				Pricing Strategy for Energy Cane			
Hybrid							
Initial	$788	$31	4	$668	$872	$724	$844
5% decrease	$716	$32	5	$594	$809	$650	$774
5% increase	$860	$30	4	$745	$941	$797	$914
10% decrease	$644	$34	5	$515	$746	$574	$706
20% decrease	$571	$36	6	$431	$687	$498	$637

Ranking of Pricing Strategies

In the previous section, the issue of risk was only indirectly addressed. For a complete analysis, risk should be given comprehensive consideration, given the precarious nature of the cellulosic ethanol industry. SD and SERF are used to examine risk and account for producer risk preferences. Figure 3.2 is a visual depiction of the Stochastic Dominance analysis for the period 2011 to 2015. According to First-Order Stochastic Dominance (FOSD) all strategies are dominated by sugarcane production, except for energy cane produced under a hybrid strategy. Of the four potential pricing strategies, the hybrid strategy FOSD both the corn and crude oil pricing strategies. According to Second-Order Stochastic Dominance (SOSD), sugar dominates all except the hybrid strategy. Figure 3.2 also shows that, under the current assumptions of the model, there is zero probability of receiving negative expected net returns per acre if energy cane is produced under a hybrid strategy. This figure provides further support for the assumption that potential processors will not induce the production of energy cane with a crude oil or corn pricing strategy unless significant changes are made to the latter two crops.

Before the SERF analysis was employed, simulation was used to determine under what conditions the hybrid strategy had the same expected net return as sugar cane production. The hybrid strategy is no longer dominated when the fixed component for realized yield is increased $0.50 per ton to $13.50. Under these new conditions, SERF is employed allowing 21 different producer risk preferences to be investigated.

Figure 3.3 shows the results from this analysis for the years 2011 to 2015. For a risk-neutral producer, a hybrid pricing strategy ($883/ac) has a higher certainty equivalent than sugar ($854), thereby inducing the production of energy cane. The certainty equivalents can interpreted as follows. If a producer were guaranteed to make $883/acre, then he or she would be indifferent to the choice between of energy cane or sugarcane. Furthermore, as the ARAC increases (i.e.

producer moves from risk neutral to risk-averse), the hybrid pricing strategy remains the preferred strategy and would stimulate the production of energy cane.[11]

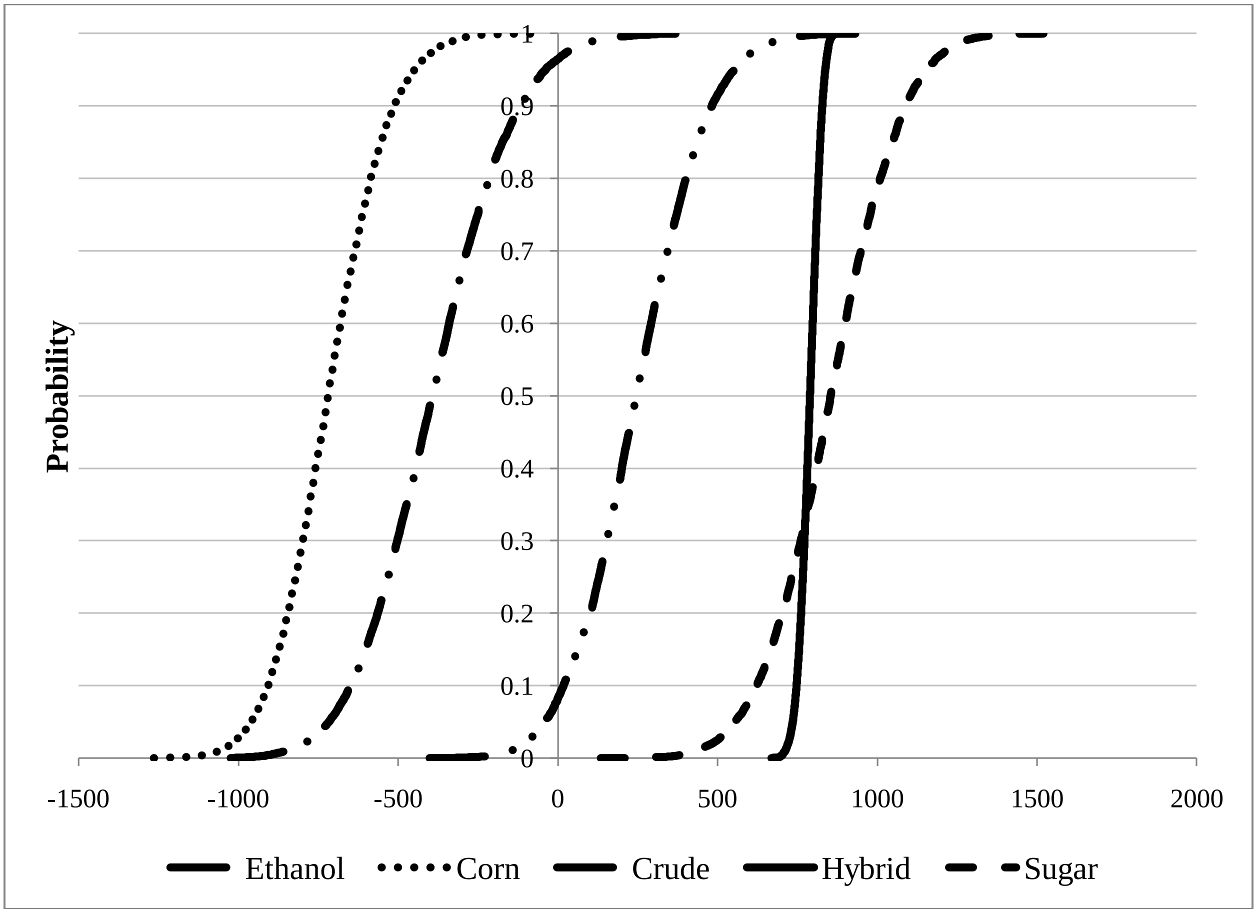

Figure 3.2: Stochastic Dominance for Total Costs of Production, 2011-2015

This is as expected, since the cellulosic ethanol industry is still in its infancy and producers want to truncate the downside risk of producing biomass for the cellulosic ethanol industry. As shown in Figure 3.3, none of the variable pricing strategies induces the production of energy cane. Ethanol is the next closet strategy to inducing energy cane production; however, as shown above in the sensitivity analysis a 28% or 12.9 percentage point increase in the feedstock share before it becomes a viable strategy for processors.

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[11] The absolute risk aversion coefficient (ARAC) is calculated as follows: $ARAC = 4/\overline{X}$; where $\overline{X}$ is the mean expected net return per acre of sugarcane.

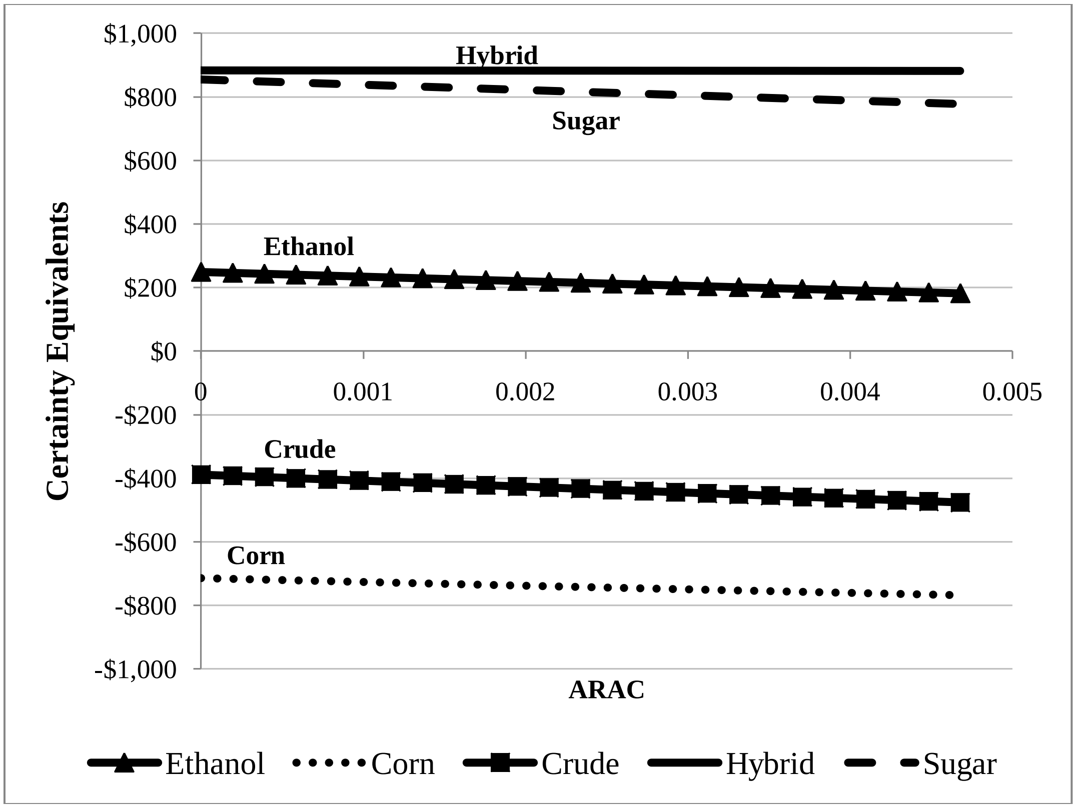

Figure 3.3: Stochastic Efficiency with Respect to a Function under a Negative Exponential Utility Function for Total Costs of Production, 2011-2015

Producer Expected Net Returns When Covering Variable Costs of Production

In the short run, producers considering the production of energy cane must cover their variable cost of production. Table 3.10 shows the percentage of the time that a producer would be able to cover their variable cost of production for the different pricing strategies and for sugarcane production. Over 10,000 iterations, it is expected that during the period 2011 to 2015, sugarcane producers will cover their variable cost of production 100% of the time. For the four pricing strategies investigated, the hybrid pricing strategy is the only one that provides a producer with the same probability of exceeding their variable cost of production as with sugarcane. Corn and crude oil pricing strategies perform poorly. However, crude oil does improve over the period as forecasted crude oil prices increase.

Table 3.10: Percentage of the Time a Producer is Above Variable Costs for Each Strategy

	Year				
	2011	**2012**	**2013**	**2014**	**2015**
Sugar	100%	100%	100%	100%	100%
Pricing Strategies for Energy Cane					
Ethanol	99%	99%	98%	98%	98%
Corn	26%	25%	24%	25%	26%
Crude	50%	53%	58%	60%	60%
Hybrid	100%	100%	100%	100%	100%

Table 3.11 contains the results for 10,000 iterations of the variable costs model for 2011. In 2011, no pricing strategy evaluated has a higher expected net return than sugar, implying that there is no incentive for risk neutral producers to grow energy cane. As expected, the hybrid pricing strategy provides producers with is the highest expected net returns ($230/acre) of the four energy cane pricing strategies examined. On average $149 per acre less than the expected net return of a sugarcane. An ethanol pricing strategy provides producers with the second highest expected net return of $197 per acre, which is on average $200 less per acre than sugarcane. Unexpectedly, corn and crude oil pricing strategies would provide producers on average -$53/acre and $21/acre, respectively. In the short run a corn pricing strategy is not a viable option for producers.

Table 3.11: Results for Pricing Strategies for Variable Costs of Production, 2011

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$379	$102	27	$23	$735	$183	$581
Pricing Strategies for Energy Cane							
Ethanol	$197	$102	51	-$104	$694	$22	$417
Corn	-$53	$90	n/a	-$285	$387	-$198	$152
Crude	$21	$121	585	-$355	$588	-$176	$290
Hybrid	$230	$19	8	$180	$265	$192	$255

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

A unique feature of the hybrid pricing strategy is that it provides producers with downside risk protection through the guaranteed percentage of cost of production. As a result of this, 95% of the simulation observations are between $192 and $255 per acre. A disadvantage of the hybrid strategy is that it slows a producer’s ability to respond to increases in input costs. Since guaranteed portion is based on historical variable production costs of the region, it takes time for the increased input cost to be reflected in regional production costs.

Table 3.12 shows the results for 10,000 iterations of 2015 expected net returns, discounted back to 2010. In 2015, there is still no strategy capable of inducing the production of energy cane based on average expected net return. The hybrid pricing strategy for a risk neutral sugarcane producer, however, narrowed the gap between itself and sugar to $104 per acre. The hybrid pricing strategy closed this gap because forecasted sugar prices decline from 2011 to 2015. Corn and crude oil pricing strategies still perform poorly.

Table 3.12: Results for Pricing Strategies for Variable Costs of Production, 2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$276	$84	31	-$19	$589	$109	$439
	Pricing Strategies for Energy Cane						
Ethanol	$164	$84	51	-$104	$508	$9	$337
Corn	-$43	$70	n/a	-$283	$274	-$167	$107
Crude	$34	$96	279	-$279	$433	-$140	$233
Hybrid	$172	$14	8	$133	$201	$143	$192

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

The hybrid pricing strategy provides producers with the lower expected net return variability, and covers variable costs 100% of the time. Over 10,000 iterations, the hybrid pricing strategy has a minimum expected net return of $133. Compared to the other pricing strategies and sugar, the hybrid pricing strategy has the advantage of providing the highest average net return of the strategies evaluated.

To determine which pricing strategy might induce energy cane production over the period from 2011 to 2015, each year’s expected net returns are summed and discounted to 2010 (Table

3.13). The hybrid pricing strategy provides producers with an expected net return of $838 per acre, the highest of the four strategies investigated. However, risk neutral producers over this period still prefer sugarcane because it provides producers with an expected net return of $1,361 per acre, $523 higher than that of the hybrid pricing strategy.

Table 3.13: Results for Pricing Strategies for Variable Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$1,361	$176	13	$644	$2,036	$1,013	$1,699
			Pricing Strategies for Energy Cane				
Ethanol	$756	$175	23	$91	$1,527	$428	$1,110
Corn	-$208	$151	n/a	-$697	$367	-$487	$106
Crude	$118	$204	173	-$542	$965	-$264	$541
Hybrid	$838	$31	4	$715	$924	$774	$894

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

For a producer preferring less variability in expected net returns per acre, the hybrid strategy provides this, by having the smallest coefficient of variation of 4, and 95% of expected net returns are between $774 and $894 per acre. As designed, this pricing strategy truncates the lower and upper tails of the net returns above variable cost. Whereas sugar has a coefficient of variation of 13 and 95% of the observations are between $1,013 and $1,699, ethanol has the third highest discounted expected net return per acre of $756, followed by crude, and corn. Corn exhibts the lowest discounted expected net return per acre of -$208. A processor considering a corn strategy even in the short run would not stimulate the production of energy cane. Thus, significant changes are needed to make the corn strategy viable.

Sensitivity Analysis

Table 3.14 contains the sensitivity analysis for the three variable strategies. For each strategy, 5, 20, and 50% increases are examined in addition to a 5% decrease in the feedstock share of cost of production. This translates into the following feedstock shares of 48.3, 55.2, 69, and 43.7, respectively. Initially this variable was set at 46%, but over time it is expected that feedstock share of costs will increase as other costs associated with the production process decrease.

Table 3.14: Results for Variable Pricing Strategies Sensitivity for Variable Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$1,361	$176	13	$644	$2,036	$1,013	$1,699
			Pricing Strategies for Energy Cane				
Ethanol							
Initial	$756	$175	23	$91	$1,527	$428	$1,110
5% decrease	$649	$168	26	$1	$1,436	$332	$993
5% increase	$864	$183	21	$149	$1,726	$522	$1,237
20% increase	$1,187	$205	17	$373	$2,161	$804	$1,606
50% increase	$1,832	$250	14	$820	$3,031	$1,366	$2,347
Corn							
Initial	-$208	$151	n/a	-$697	$367	-$487	$106
5% decrease	-$267	$145	n/a	-$714	$343	-$538	$34
5% increase	-$148	$157	n/a	-$633	$510	-$438	$174
20% increase	$30	$174	586	-$512	$761	-$289	$390
50% increase	$386	$211	55	-$274	$1,262	$3	$826
Crude							
Initial	$118	$204	173	-$542	$965	-$264	$541
5% decrease	$43	$196	460	-$653	$866	-$324	$448
5% increase	$194	$214	110	-$547	$1,100	-$203	$638
20% increase	$421	$241	57	-$398	$1,449	-$27	$921
50% increase	$875	$296	34	-$112	$2,148	$323	$1,493

* n/a indicates a negative coefficient of variation and in infeasible region of risk frontier

An ethanol pricing strategy assuming an initial 46% feedstock share will not induce energy cane production. A 20% or 9.2 percentage point increase in feedstock share only yields $1,187 per acre, which is on average $174 per acre less than sugarcane producers will earn over the period 2011 to 2015. For an ethanol pricing strategy to become a viable option, producers need the feedstock share of cost of production to increase by more than 20% or 9.2 percentage points. To make a corn strategy viable a processor would have to increase the feedstock share to

100% and find addition methods to increase the $/t paid to producers. For the crude oil pricing strategy, more than a 50% or 23 percentage point increase in feedstock share is required for this strategy to induce energy cane production.

The hybrid pricing strategy had the highest expected net returns of the strategies investigated, but it still did not induce the production of energy cane. A key driver for this strategy is the guaranteed percentage of the production costs and Table 3.15 contains the results for 5, 10, and 15 percent decreases this variable. Additionally, a 5% increase in this variable is examined. Over time, it is expected that processors will not want to continue paying this guaranteed portion to producers after the industry begins to mature. Until this happens, processors could increase the guaranteed portion to 100% and still not reach a level to induce energy cane production. At a 5% or 4.5 percentage point increase to 94.5%, the hybrid strategy has an average expected net return of $894 per acre. This is on average $467 per acre lower than sugarcane.

Table 3.15: Results for Hybrid Pricing Strategies Sensitivity for Variable Costs of Production, 2011-2015

						95% Confidence Interval	
	Mean	**StDev**	**CV**	**Min**	**Max**	**Lower**	**Upper**
Sugar	$1,361	$176	13	$644	$2,036	$1,013	$1,699
			Pricing Strategy for Energy Cane				
Hybrid							
Initial	$838	$31	4	$715	$924	$774	$894
5% decrease	$784	$31	4	$673	$861	$722	$842
5% increase	$894	$29	3	$788	$965	$834	$947
10% decrease	$729	$32	4	$615	$815	$664	$790
20% decrease	$674	$34	5	$558	$769	$607	$737

Ranking of Pricing Strategies

FOSD, SOSD, and SERF are used to examine risk. Figure 3.4 shows the results of the FOSD analysis over the full time period 2011 to 2015. According to FOSD and SOSD, producers should continue the production of sugarcane to be used in the production of sugar. Sugar FOSD all pricing strategies except the hybrid pricing strategy. In that case, only risk-neutral producers would choose to engage in sugarcane production. As for risk-averse producers, they would continue to produce sugarcane in accordance with SOSD dominating the hybrid strategy. Thus none of the potential pricing strategies would not induce the production of energy cane risk averse producer.

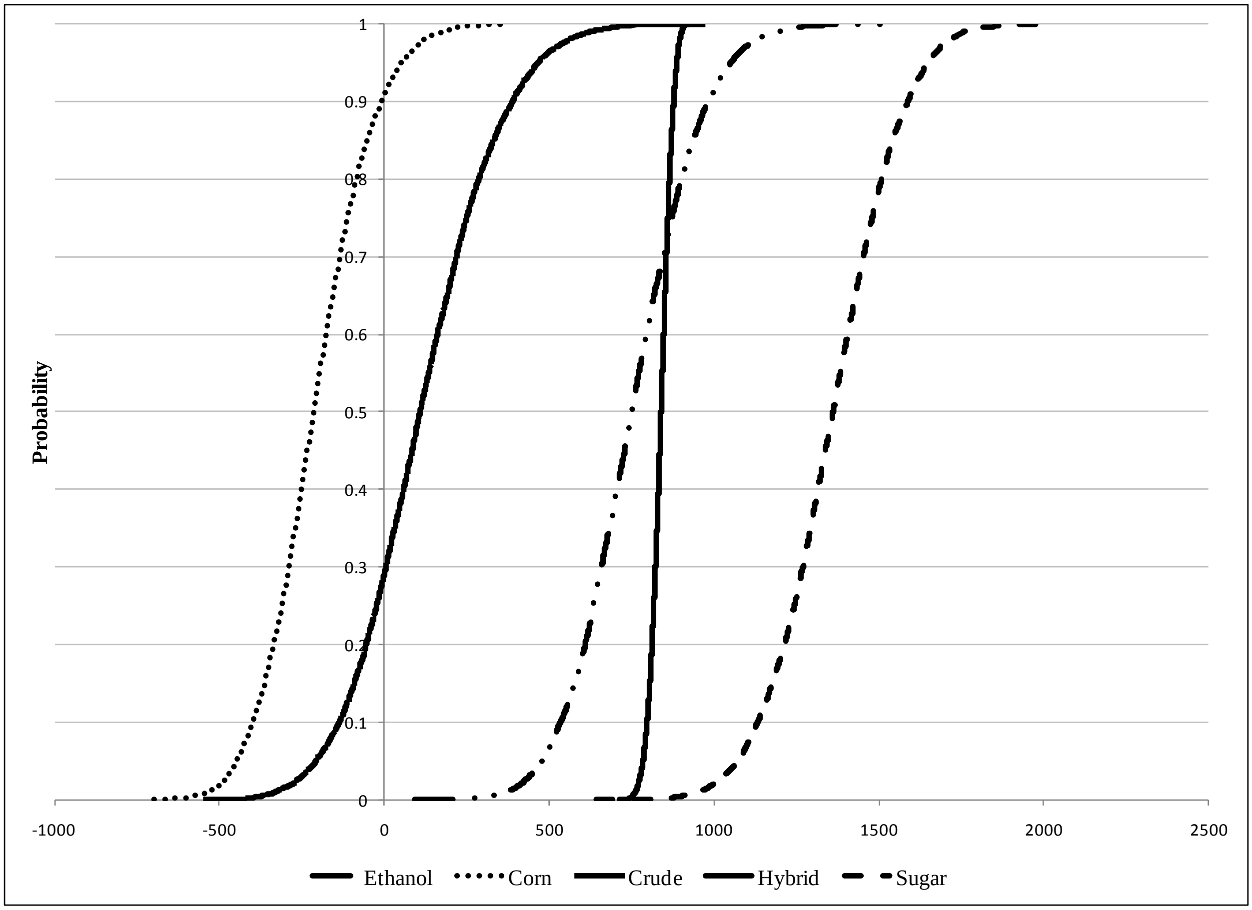

Figure 3.4: Stochastic Dominance for Variable Costs of Production, 2011-2015

Before the SERF analysis is employed, it is determined that through a 90% cost of production guarantee and an increase of $5.50 per ton to $18.50 per ton, the hybrid pricing strategy is no longer FOSD or SOSD by sugar. SERF is now used to rank the different pricing strategies after the hybrid pricing strategy is altered.[12] Figure 3.5 shows the results for the SERF analysis performed on all strategies for the period 2011 to 2015. For risk-neutral producers, a hybrid pricing strategy provides producers with a certainty equivalent of $1,366/acre compared to sugar of $1,361/acre. Under this hybrid pricing strategy, producers are almost indifferent between the production of energy cane and sugarcane. Furthermore, as the ARAC increases (i.e., producer becomes more risk averse), the hybrid pricing strategy remains the preferred strategy. As shown with FOSD, none of the variable pricing strategies induces the production of energy cane.

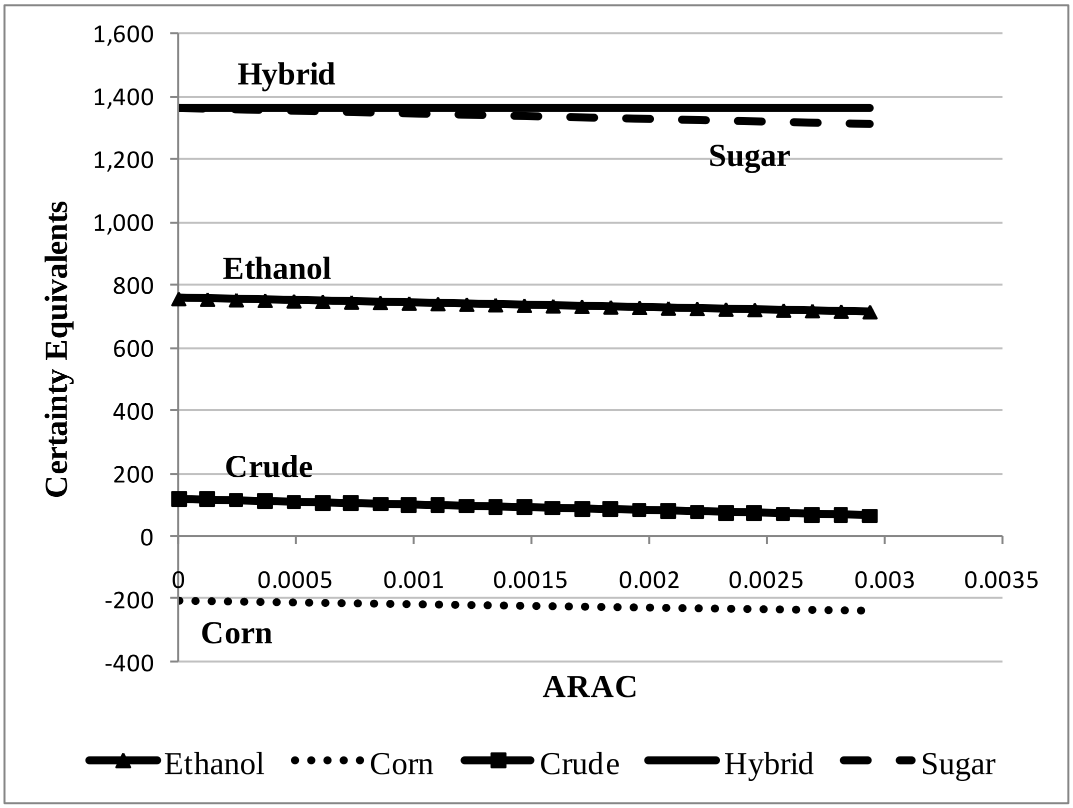

Figure 3.5: Stochastic Efficiency with Respect to a Function under a Negative Exponential Utility Function for Variable Costs of Production, 2011-2015

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[12] The increase of $5.50 per ton is determined through a series of simulations. In each simulation the non-discounted are used so that a specific dollar amount for 2015 can be determine. Then each simulation is examined to determine FOSD and SOSD.

Conclusions and Discussion

In this paper, the introduction of energy cane into the crop portfolio is examined for two different production costs. In the long run, a producer must cover his or her total cost of production (i.e., fixed, variable, and overhead costs). However, the disadvantage to using total costs is that net returns per acre are understated because the fixed cost component is based upon new equipment prices. Typically, new equipment is not purchased yearly so variable costs of production are considers instead.

Four different biomass pricing strategies are considered in this study. These different pricing strategies can be broken down into three different variable pricing strategies and one hybrid strategy. Expected net returns for the pricing strategies are then compared to sugarcane expected returns per acre, the primary crop produced in this area of Louisiana.

For producers considering energy cane production, a hybrid pricing strategy provides the highest expected net return of the pricing strategies investigated, regardless of whether the producer is assumed to be covering variable or total costs. An ethanol pricing strategy yielded the second highest expected net return for the strategies investigated for a producer covering either total or variable costs. Corn and crude oil pricing strategies preformed the poorest of the strategies investigated and both had negative expected net returns when covering total costs. However, the expected net returns for all these strategies are lower than the production of sugarcane. Therefore, from a producer prospective, the preferred strategy is to continue production of sugarcane, according to FOSD and SOSD, and irrespective of risk preferences.

From a processor's point of view, significant changes are needed to stimulate biomass production. For the hybrid pricing strategy, adjusting the guaranteed portion of the contract to 94.5% from 90% could potentially induce the production of energy cane. Another option the processor has is to increase the variable portion of the hybrid strategy, by $0.50/t. For the ethanol pricing strategy, the feedstock share must be increased by 12.9 percentage points from its starting point of 46% to 58.9%, if a producer is going to cover total costs. It is expected that this can be achieved as the industry matures and enzyme and capital costs decrease. To make corn and crude oil strategies viable, processors considering these strategies must make significant increases in the feedstock share and add another component increasing the $/t producers receive.

This study provides producers and processors with a framework for evaluating different pricing strategies, along with four potential pricing strategies. To induce the production of biomass, processors will have to pay producers a price for that biomass that is at least equal to the expected net returns they are receiving with the crops currently being produced. Of the four pricing strategies investigated in this study, none would provide producers with the same expected net return from sugarcane. Processors should therefore look to making changes in their pricing strategies in order to induce biomass production.

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CHAPTER 4: WHAT DOES THE INTRODUCTION OF ENERGY CROPS MEAN FOR THE CROP MIX AND CELLULOSIC ETHANOL PLANT LOCATION IN LOUISIANA?

Introduction

In recent years the Mississippi Delta has undergone some significant cropland allocation changes spurred partially by both energy and farm policies, including those directly affecting the ethanol industry. Significant energy policies that have influenced the expansion of the ethanol industry are the banning of methyl tertiary butyl (MTBE), the 2005 Energy Policy Act, and the 2007 Energy Independence and Security Act. A new Renewable Fuels Standard (RFS) was passed in 2007 with the ratification of the Energy Independence and Security Act (EISA), mandating that fuel producers use at least 36 billion gallons of biofuels by 2022 and placed an emphasis on the production of cellulosic ethanol (OPS, 2007). The Food, Conservation, and Energy Act of 2008 is also beginning to play a role with the implementation of the Biomass Crop Assistance Program (BCAP) that helps to defray some of the establishment costs of these crops.

With the implementation of these new policies, several states, especially those in the Mississippi Delta, are beginning to see significant changes in crop acreage allocations. For example, in Arkansas, Louisiana, and Mississippi, the planted acres of cotton from 2006 to 2007 dropped by 26, 47, and 46 percent, respectively (USDA, 2009). The lost cotton acres in these states were replaced almost one for one with corn acres. A potential reason for this drastic switch is that, U.S. corn prices, on average, were \$2.00 and \$1.16 higher per bushel than in 2005 and 2006, respectively. These changes in cropland allocations are beginning to change the face of the Mississippi Delta agricultural landscape as producers respond to market signals to increase the production of crops used in biofuel production (Figure 4.1).

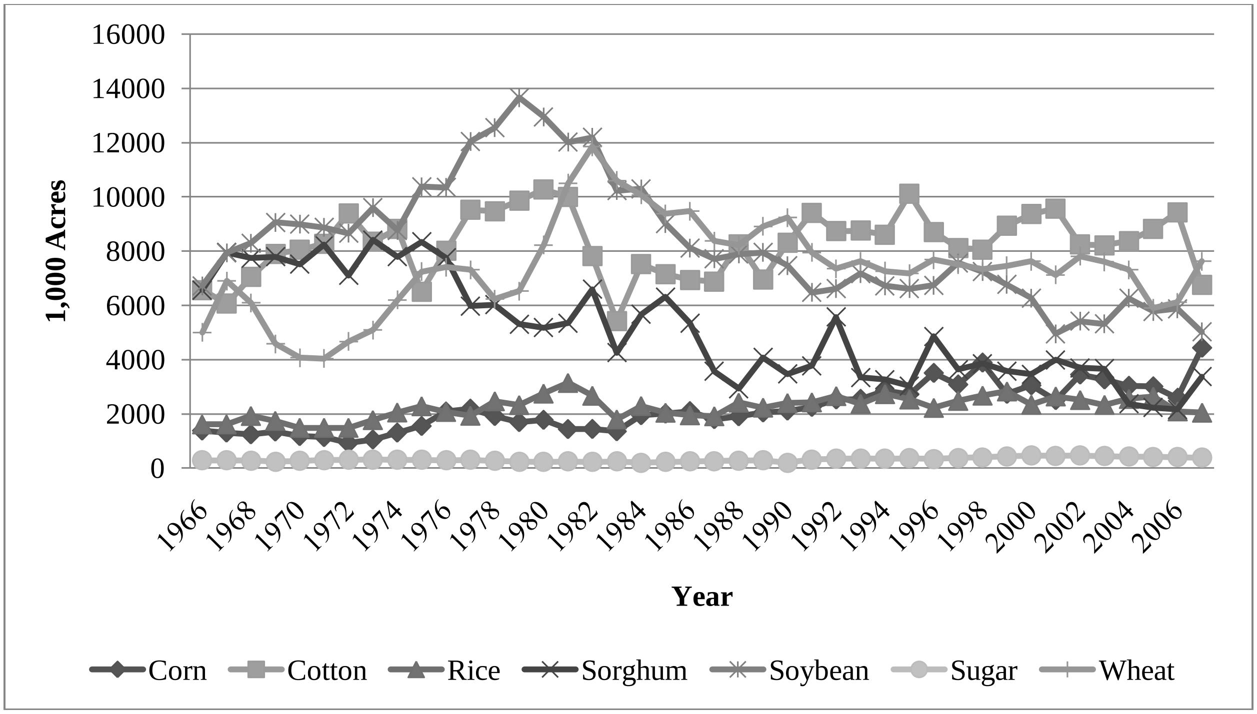


Figure 4.1: Historical Distribution of Primary Crop Acreages for Mississippi Delta

With the introduction of second generation biofuels, there potentially could be further cropland allocation changes. This is going to be highly dependent upon the crops available for production in a given region. Some of the crops that are being considered for use in second generation biofuels are switchgrass, hybrid poplar, energy cane, sweet sorghum, and miscanthus. Given that Louisiana has a fixed amount of land available for crop production, the introduction of any of these crops could further alter the agricultural landscape. Furthermore, many of the potential energy crops used in the production of second generation biofuels are not traditionally grown in the state. The only exception to this might be energy cane, which is essentially a high fiber sugarcane variety (ASCL, 2007).

This study specifically focuses on farming in the Louisiana Sugarcane Belt as farmers in this region are looking for additional crops to add into their crop portfolio because of stagnant sugar prices and rising input costs. The Sugarcane Belt of Louisiana is a small area comprised of 22 parishes in Southern Louisiana (Figure 4.2) that only produces sugarcane, rice, and soybeans.

This study considers the introduction of energy cane into the portfolio of potential crops that can be grown on the farms in the Sugarcane Belt. Over time, the size of the Sugarcane Belt has decreased with low sugar prices; the introduction of energy cane into the region could begin an expansion of the Belt. This study, however, only examines those parishes currently producing sugarcane. Future studies in this area will be expanded. The first objective is to examine the potential changes in the crop mix for 2011, given different pricing strategies used by processors to entice producers to switch into the production of energy cane. This is accomplished by maximizing the expected net returns above variable cost for producers on a parish basis. Returns above variable costs are considered because in the short run, a producer only has to cover variable costs and using fixed costs, leads to an underestimation of expected net returns as fixed costs are based on new equipment purchase prices. The potential changes in land allocations for each parish could have significant impacts on a biofuel feedstock processor's location decision. A key variable, which processors need to consider when locating a plant, is its proximity to feedstock production, in an effort to minimize transportation costs. The second objective of this paper is to determine optimal cellulosic ethanol plant location(s) based on minimizing the transportation costs of energy cane. The third objective is to investigate the sensitivity of key variables to changes and their influence on crop mix and optimal plant location.

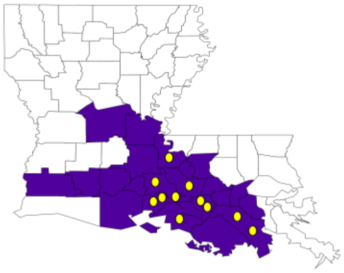


Figure 4.2: The Louisiana Sugarcane Belt and Sugar Mill Locations

Literature Review

Optimal Crop Mix

Since many of the crops that can be used as energy crops are nontraditional crops; it is unknown how the introduction of these energy crops could impact the crop mix in a given parish, region, or state. While literature addressing the issue of energy crop introduction is still in the developmental stages, optimal crop mix models, however, have been employed in numerous other areas of agriculture. Sarker et al. (1997) employ an optimization model to determine the optimal crop mix by maximizing the contribution of each crop to the nation of Bangladesh. Ekman (2000) maximizes a producer's expected revenue by optimizing a producers' equipment size. Amir and Fisher (2000) employ a nearly optimal crop optimization model to maximize the net income of a given region in Israel. This study seeks to maximize the expected per acre net return for each parish in the Louisiana Sugarcane Belt and determine a new optimal crop mix for the region once energy cane is introduced.

Optimal Plant Location

Determining the optimal locations for cellulosic ethanol processing facilities is a key step in the cellulosic ethanol supply chain. Noon and Daly (1996) and Zhan et. al. (2005) finds that cellulosic ethanol processing facility profitability is highly dependent upon location. Biomass production and transportation account for a large portion of bioenergy costs. All of the studies examined below share a common goal of supplying the quantity demanded to the processing facility at least cost.

Numerous studies employ the usage of GIS-based systems to find optimal locations (Panichelli and Gnansounou, 2008; Nord-Larsen and Talbot, 2004; Krukanont and Prasertsan, 2004; Graham et al., 2000; Graham et. al., 1997; and Noon et. al., 1996). Using a GIS-based platform to determine plant location allows for distances from one location to another to be determine using actual rode distances. However, just the usage of GIS is not enough. Linear programming models are typically used to minimize transportation costs. Noon et al. (1996) and Graham et al. (1997), find that the available supply of biomass, farm-gate costs, and transportation costs vary drastically even within a state's borders. In order to address these issues, they employ a Regional Integrated Biomass Assessment (RIBA) system. This system incorporates two different phases. First, the surface model is used to combine farm-gate prices and supplies with a transportation algorithm to determine the marginal cost of delivery to all possible locations. Second, a location model is employed that uses the same farm-gate prices and supplies in conjunction with a plant location algorithm to determine the least cost locale(s). Another method that could be implemented is the Biomass Resource Assessment Version One (BRAVO) system, which employs a GIS platform to develop delivered cost supply curves for a given location (Graham et al., 1997). From this study, they find that the usage of farm-gate price data in conjunction with uniform transportation costs can result in misleading results and overlook obscure opportune locations.

Methodology

In order to determine the optimal crop mix within the region, expected net returns above variable costs (ENR) are maximized for each parish. The optimal crop mix model takes into consideration all land in farms or 3.2 million acres for the 22 parishes producing sugarcane in 2008 (AgSummary, 2010). For the Sugarcane Belt in 2009 rice, soybeans, and sugarcane accounted for 314,844 acres, 420,825 acres, and 417,869 acres, respectively (AgSummary, 2010). Within this region, it is expected that the introduction of energy cane could significantly change crop allocations in the region. These crop allocation changes are investigated for 2011 and 2015. Furthermore, it is expected that soybeans will be the primary crop that observes decreases in acreages because low yield relative to other regions of the country and smaller government payments relative to rice. After determining the optimal crop mix the optimal location for a cellulosic ethanol processing facility to minimize feedstock transportation costs can be determined.

Expected Net Returns Simulation

Expected net returns above variable costs (ENR) for each are forecasted for 2011 to 2015, via simulation. ENR per acre are calculated as shown in equation 4.1,

$$ENR = (y_{it} * p_{it}) + g_{it} - c_{it}\,, \tag{4.1}$$

where *y* is the yield, *p* is the price, *g* is the government payment, *c* is the variable cost, *i* is crop, and *t* is time. Yields, prices, and variable costs of production are simulated for energy cane, rice, soybeans, and sugarcane. Each variable is discussed below in addition to how government payments are calculated for rice and soybeans.

A multivariate empirical distribution is used to simulate expected yields for energy cane and sugarcane. Energy cane is not currently being produced commercially; therefore, yields are based upon sugarcane yield. A caveat to this is that energy cane yields are adjusted up to 35 tons/acre from the 30 tons/acre average of sugarcane. Rice and soybean yields also make use of the multivariate empirical distribution to allow for the yields of these enterprises to be correlated.

Prices for all crops except for energy cane are simulated use Gray-Klose-Richardson-Schumann (GRKs) distribution. GRKs is similar to a triangle distribution in that it requires a minimum, midpoint, and maximum value. However, unlike the triangular distribution, it allows for sampling above and below the minimum and maximum a small percentage of the time (Richardson et al., 2008). Minimum and maximum values for each crop are extracted from 2000-

2009 historical crop prices. The 2010 FAPRI Baseline projections provide the midpoints for each crop price.

The market of biomass is still in its infancy stages and pricing methods still being developed. Therefore, two different pricing strategies for energy cane are considered in this analysis. First is an ethanol pricing strategy. The price per ton of energy cane a producer will receive under a variable ethanol pricing strategy, Equation 4.2 is used,

$$prodeth = ((tethp * galperac)/tonperac) * feed\%, \tag{4.2}$$

where *prodeth* is the dollars per ton ($/t) paid to producers, *galperac* is gallons per acre (gal/ac) of ethanol production, *feed%* is feedstock's portion of the cost of production, *tethp* is ethanol price in dollars per gallon ($/gal), and *tonperac* is the tons of energy cane produced per acre. Gallons of ethanol per acre is calculated by assuming average energy cane yields are 35 tons per acre (*tonperac*) and a lignocellulosic ethanol plant can produce 24.58 gal/t of biomass. As an initial starting point, *feed%* is assumed to be 46 percent in accordance with Collins (2007). The last component needed to determine the producers' price is a forecast of ethanol price (*tethp*). Ethanol price forecasts are taken from the 2010 FAPRI Baseline. This forecast provides the mean to be used in a GRKs distribution. Second, a hybrid pricing strategy is a two-tiered strategy that contains a guaranteed and variable component. Equation 4.3 shows how the hybrid producer (*prodhybrid*) price is determined;

$$prodhybrid = ttotcost * guarantee + tonperac * real, \tag{4.3}$$

where cost of production less harvest costs (*ttotcost*) is in $/ac, *guarantee* is 90 percent of the production cost guaranteed by the processor plus a fixed price (*real*) from the processor for each realized ton of production per acre of energy cane *tonperac*.

Government payments are included as they can play a significant role in a producer's decision on whether or not to produce a crop. Of the crops considered in this analysis, only rice and soybeans are eligible to receive government payments. Government payments for rice are based upon established program yields and a direct payment of \$2.35 per cwt for each producer. Soybean payments are based upon average program yields from 1988-2001 and a direct payment of \$0.44 per bushel. Individual producer data is not available; therefore, yields for each crop are based the parish average. Counter-cyclical and Loan Deficiency Payments are not included as prices within the time frame studied are higher than the target prices required for these payments to be dispersed.

Variable costs of production are also simulated using GRKs. Minimums and maximums are extracted from the 2005-2009 enterprise budgets for each crop, produced by the Louisiana State University Agricultural Center. The midpoint is determined by taking the average of the variable production costs over the period 2005-2009.

Optimal Crop Mix

The objective function of the optimal crop mix model is shown in Equation 4.4

$$\max Z = \sum_{j=1}^{n} ENR_i AC_j \quad , \tag{4.4}$$

where *ENR* is the expected net returns above variable costs per acre, *AC* is acres, *i* is crop, and *j* is parish. For each crop (*i*) are multiplied by acres (*AC*) in each parish (*j*).

The constraints for this model are outlined in Equations 4.5-4.8. Equation 4.5,

$$\sum_{i=1}^{m} l_i \leq usable_j \quad , \tag{4.5}$$

where *l* total crop acres, *usable* is total farmland acres in the parish, *i* is crop, and *j* is parish. This equation limits the total acres of all crops to be less than or equal to the total land in farms in each parish.

It is not expected that there will be significant shifts in crop acreages. For example, the average rice acreage in Acadia Parish over the past three years has been 12,000 acres; therefore, the minimum and maximum would be set at plus or minus 5 percent from the average acreage. The reason for doing this is that sugarcane is a perennial crop, which makes it difficult and expensive to plow out and start over. Furthermore, rice is a program crop and many producers will choose to continue planting 85 percent of their base in order to continue receiving government payments. To control for this Equation 4.6 and 4.7 are added. Equation 4.6 represents the minimum allowable acreage for each crop,

$$a_{ij} \geq \min_{ij} \ , \tag{4.6}$$

where *a* is acreage, *min* is the minimum acreage allowed, for crop *i* in parish *j*. Equation 4.7 represents the maximum allowable acreage for each crop,

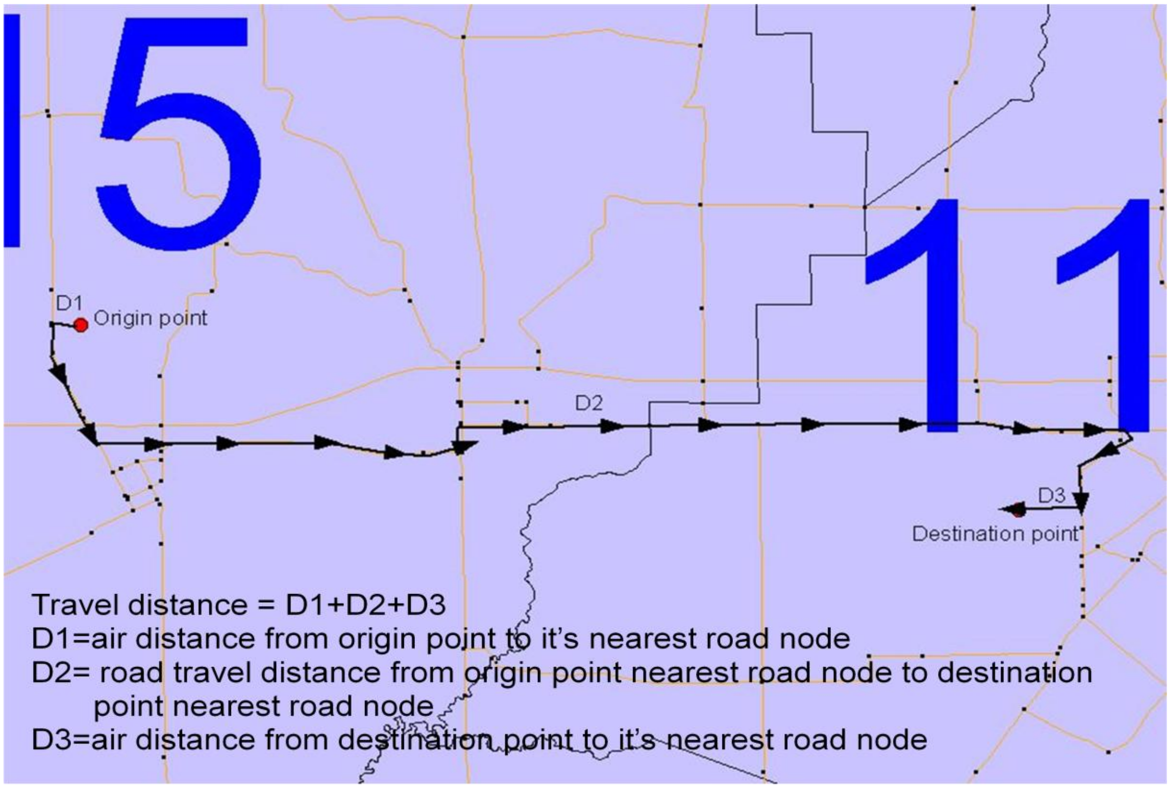
$$a_{ij} \leq \max_{ij} \tag{4.7}$$

where *a* is acreage, *max* is the maximum acreage allowed, for crop *i* in parish *j*.

Plant Location

Optimal location of cellulosic ethanol processors is the last aspect of this framework that is investigated. The introduction of energy cane into the portfolio influences the optimal crop mix for the state; likewise, it influences the least cost location(s) of potential cellulosic ethanol plants using energy cane. Now using the optimal crop mix for each parish, the optimal location for a cellulosic ethanol processing facility based on transportation costs is determined.

Geographic information system (GIS) software is used to map all of the potential routes that could be used in the transportation of biomass from the centroid of one parish to the next. A depiction of how distance calculations are carried out in this model is shown in Figure 4.3.



Travel distance = D1+D2+D3
D1=air distance from origin point to it's nearest road node
D2= road travel distance from origin point nearest road node to destination point nearest road node
D3=air distance from destination point to it's nearest road node

Figure 4.3: Depiction of Distance Calculation

It should be noted that the accuracy of this calculation would increase if the distance between every field and each possible ethanol plant location could be determined; however, this information is not available. GIS provides a distance matrix and the optimal location(s) based on the lowest transportation costs can be determined dependent on the number of processors in the in the region.

The object function of the transportation cost minimization is represented in equation 4.8,

$$\min Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \quad , \qquad (4.8)$$

where Z is total cost, c is cost of transportation, x is the tons of biomass, i is the supply parish, and j is the demand parish. The constraints of the model are represented in equation 4.9-4.11. In order to ensure that all biomass produced is shipped a processor(s) Equation 4.9 is employed,

$$\sum_{j=1}^{n} x_i = s_{ij} \ , \tag{4.9}$$

where *x* is tons of biomass, *s* is total biomass to be shipped, *i* is the shipping parish, and *j* is the receiving parish. Likewise, all biomass must be received as represented in Equation 4.10,

$$\sum_{i=1}^{m} x_j = d_{ij} \tag{4.10}$$

where *x* is tons of biomass, *d* is the total biomass to be received, *i* is the shipping parish and *j* is the receiving parish. Depending on the amount of biomass produced, the number of processing facilities may need to be adjusted. To allow this adjustment to be made Equation 4.11 is employed,

$$\sum_{i=1}^{22} y_i = plants \tag{4.11}$$

where *y* dummy for processing plant, *plants* is the number of processing plants desired and *i* is parish.

Data

Data for yields, production acreages, land in farms, and number of farms is collected from AgSummary (2010). Rice, soybean, and sugarcane prices for 2010-2015 are obtained from Food and Agricultural Policy Research Institute (FAPRI) (2010) baseline projections. Production costs for each of the crops are forecasted using Louisiana State University Production Budgets (Salassi and Deliberto, 2007, 2008, 2009, 2010(a); Salassi and Deliberto, 2007, 2008, 2009, 2010(b); Salassi and Breaux, 2005, 2006(a); Salassi and Breaux, 2005, 2006 (b)). Distances from one parish centroid to the next are determined using GIS software.

Results

In general, the results confirmed expectations that the introduction of energy cane into the Sugarcane Belt changes producer land allocations. The primary crop that energy cane replaces is soybeans. For 2009, the optimal crop mix model had a prediction error of -3%, 6%, and 1% for rice, soybeans, and sugarcane, respectively. Using new optimal crop mixes the optimal plant location model as expected finds the optimal plant location(s) are on the periphery of the Sugarcane Belt. For both 2011 and 2015, St. Landry Parish is the optimal single plant location no matter whether an ethanol or hybrid pricing strategy is employed for biomass pricing.

Optimal Crop Mix

The introduction of energy cane into the production portfolio alters the land allocations of producers in the region, assuming they profit maximize. Without the introduction of energy cane, expected net revenue above variable costs for the Belt is $361,369,789, in 2011. For 2011, if energy cane was in full production and processors employed a hybrid pricing strategy 27,792 acres of energy cane is produced, increasing the expected net return for the region by $2,949,465 to $364,319,254 for 2011. Table 4.1 shows the geography dispersion of energy cane acres throughout the Belt under “Optimal Crop Mix with Energy Cane”, when a hybrid pricing strategy is employed by processors. To provide a comparison the table also contains the projected crop mix under “Base” using forecasted prices for each of the crops. With the introduction of energy cane, soybean acres decrease one-for-one. Soybeans provide producers with the lowest expected net returns per acre because of expected low yields and prices. Furthermore, the largest majority of energy cane acres entering the model lie on the periphery of the Sugarcane Belt. The majority of soybean acres that are converted to energy cane production are located on the Northwest periphery of the Belt in Rapides, Evangeline, Avoyelles, and St.

Landry counties. Furthermore, these parishes are of interest because as shown in figure 4.2, the majority of sugar mills are located in the Southern portion of the Belt and increasing transportation costs are making infeasible to continue transporting sugarcane from these counties

Table 4.1: 2011 Cropland Allocations with Hybrid Pricing Strategy for Energy Cane

	Base (ac)			Optimal Crop Mix with Energy Cane (ac)			
Parish	**Rice**	**Soybean**	**Sugarcane**	**Rice**	**Soybean**	**Sugarcane**	**Energy Cane**
Acadia	77,607	44,603	2,089	77,607	40,355	2,089	4,248
Ascension	-	1,042	16,985	-	943	16,985	99
Assumption	-	-	35,090	-	-	35,090	965
Avoyelles	16,156	75,421	9,709	16,156	70,599	9,709	4,823
Calcasieu	12,156	4,156	2,790	12,156	3,769	2,790	910
Evangeline	41,588	23,911	343	41,588	21,634	343	2,278
Iberia	409	6,713	55,817	-	6,713	55,817	429
Iberville	-	9,718	34,346	-	9,718	34,346	-
Jefferson Davis	77,980	16,940	4,953	77,980	15,327	4,953	1,613
Lafayette	3,717	6,538	12,205	3,717	5,919	12,205	623
Lafourche	-	-	26,173	-	-	26,173	280
Pointe Coupee	2,700	65,374	32,661	2,700	65,375	32,661	-
Rapides	10,417	30,916	10,889	10,417	28,430	10,889	2,487
St. Charles	-	-	1,613	-	-	1,613	-
St. James	-	-	26,917	-	-	26,917	327
St. John	-	-	7,280	-	-	7,280	315
St. Landry	24,703	84,203	7,555	24,703	78,657	7,555	5,546
St. Martin	4,585	8,111	30,828	4,585	7,339	30,828	773
St. Mary	285	3,645	43,924	285	3,298	43,924	377
Terrebonne	-	-	9,595	-	-	9,595	457
Vermilion	53,594	7,186	29,448	53,594	6,501	29,448	685
West Baton Rouge	-	5,839	14,401	-	5,283	14,401	557
Total	325,897	394,316	415,611	325,488	369,860	415,611	27,792

Another pricing option that a processor could use to induce the production of energy cane in the region is pricing relative to ethanol. Under this pricing strategy, expected net revenue above variable costs for the Belt is $363,507,354 or $811,900 less than what is expected under a hybrid pricing strategy. Table 4.2 shows the geographic dispersion of crop acreages when a processor implements an ethanol pricing strategy. This is as expected since on a per acre basis the hybrid pricing strategy provides a producer with higher returns than does the ethanol strategy. However, under the ethanol strategy expected net returns for energy cane are still higher than soybean production. The ethanol option induces 514 less acres of energy cane production relative to the hybrid strategy, with Calcasieu being the parish that decreases production.

Table 4.2: 2011 Cropland Allocations with Ethanol Pricing Strategy for Energy Cane

	Base (ac)			Optimal Crop Mix with Energy Cane (ac)			
Parish	**Rice**	**Soybean**	**Sugarcane**	**Rice**	**Soybean**	**Sugarcane**	**Energy Cane**
Acadia	77,607	44,603	2,089	77,607	40,355	2,089	4,248
Ascension	-	1,042	16,985	-	1,042	16,985	99
Assumption	-	-	35,090	-	-	35,090	965
Avoyelles	16,156	75,421	9,709	16,156	70,599	9,709	4,823
Calcasieu	12,156	4,156	2,790	12,156	3,769	2,790	396
Evangeline	41,588	23,911	343	41,588	21,634	343	2,278
Iberia	409	6,713	55,817	-	6,713	55,817	429
Iberville	-	9,718	34,346	-	9,718	34,346	-
Jefferson Davis	77,980	16,940	4,953	77,980	15,327	4,953	1,613
Lafayette	3,717	6,538	12,205	3,717	5,915	12,205	623
Lafourche	-	-	26,173	-	-	26,173	280
Pointe Coupee	2,700	65,374	32,661	2,700	65,375	32,661	-
Rapides	10,417	30,916	10,889	10,417	28,430	10,889	2,487
St. Charles	-	-	1,613	-	-	1,613	-
St. James	-	-	26,917	-	-	26,917	327
St. John	-	-	7,280	-	-	7,280	315
St. Landry	24,703	84,203	7,555	24,703	78,657	7,555	5,546
St. Martin	4,585	8,111	30,828	4,585	7,339	30,828	773
St. Mary	285	3,645	43,924	285	3,298	43,924	377
Terrebonne	-	-	9,595	-	-	9,595	457
Vermilion	53,594	7,186	29,448	53,594	6,501	29,448	685
West Baton Rouge	-	5,839	14,401	-	5,283	14,401	557
Total	325896.5	394316	415611	325488	369955	415611	27278

Over time, it is expected that crop mix will continue to change and producers will continue to respond to market signals. Therefore, crop mixes are again examined for the two different pricing strategies for 2015. For 2015, expected net return above variable for the region is $368,024,896, which is $3,103,085 less than what is expected with energy cane production and a hybrid pricing strategy. However, under the hybrid strategy, energy cane acres are expected to decrease from 2011 level to 27,278 acres, as soybean prices increase in 2015 over their forecasted 2011 level.

Table 4.3: 2015 Cropland Allocations with Hybrid Pricing Strategy for Energy Cane

	Base (ac)			Optimal Crop Mix with Energy Cane (ac)			
County	**Rice**	**Soybean**	**Sugarcane**	**Rice**	**Soybean**	**Sugarcane**	**Energy Cane**
Acadia	77,607	44,603	2,089	77,607	40,355	2,089	4,248
Ascension	-	1,042	16,985	-	943	16,985	99
Assumption	-	919	35,090	-	-	35,090	965
Avoyelles	16,156	75,421	9,709	16,156	70,599	9,709	4,823
Calcasieu	12,126	4,165	2,790	12,156	3,769	2,790	396
Evangeline	41,588	23,911	343	41,588	21,634	343	2,278
Iberia	409	6,713	55,817	-	6,713	55,817	429
Iberville	-	9,718	34,346	-	9,718	34,346	-
Jefferson Davis	77,980	16,940	4,953	77,980	15,327	4,953	1,613
Lafayette	3,717	6,538	12,205	3,717	5,915	12,205	623
Lafourche	-	267	26,173	-	-	26,173	280
Pointe Coupee	2,700	65,374	32,661	2,700	65,375	32,661	-
Rapides	10,417	30,916	10,889	10,417	28,430	10,889	2,487
St. Charles	-	-	1,613	-	-	1,613	-
St. James	-	311	26,917	-	-	26,917	327
St. John	-	364	7,280	-	-	7,280	315
St. Landry	24,703	84,203	7,555	24,703	78,657	7,555	5,546
St. Martin	4,585	8,111	30,828	4,585	7,339	30,828	773
St. Mary	285	3,645	43,924	285	3,298	43,924	377
Terrebonne	-	-	9,595	-	-	9,595	457
Vermilion	53,594	7,186	29,448	53,594	6,501	29,448	685
West Baton Rouge	-	5,839	14,401	-	5,283	14,401	557
Total	325,867	396,186	415,611	325,488	369,856	415,611	27,278

Calcasieu Parish is the only parish that decreases energy cane production from 2011 to 2015 and increases soybean acreages. Otherwise, the production acreage of energy cane remains the same in the rest of the Belt.

Under and ethanol pricing strategy in 2015, energy cane acres decrease to 27,179 compared to the hybrid strategy of 27,278. This 99 acre decease in energy cane acres lowers the expected net return for the Belt to $370,698,738. Ascension Parish is where this decrease in acreage occurs. Otherwise, all other acreages remain the same.

Table 4.4: 2015 Cropland Allocations with Ethanol Pricing Strategy for Energy Cane

	Base (ac)			Optimal Crop Mix with Energy Cane (ac)			
County	**Rice**	**Soybean**	**Sugarcane**	**Rice**	**Soybean**	**Sugarcane**	**Energy Cane**
Acadia	77,607	44,603	2,089	77,607	40,355	2,089	4,248
Ascension	-	1,042	16,985	-	1,042	16,985	-
Assumption	-	919	35,090	-	-	35,090	965
Avoyelles	16,156	75,421	9,709	16,156	70,599	9,709	4,823
Calcasieu	12,126	4,165	2,790	12,156	3,769	2,790	396
Evangeline	41,588	23,911	343	41,588	21,634	343	2,278
Iberia	409	6,713	55,817	-	6,713	55,817	429
Iberville	-	9,718	34,346	-	9,718	34,346	-
Jefferson Davis	77,980	16,940	4,953	77,980	15,327	4,953	1,613
Lafayette	3,717	6,538	12,205	3,717	5,915	12,205	623
Lafourche	-	267	26,173	-	-	26,173	280
Pointe Coupee	2,700	65,374	32,661	2,700	65,375	32,661	-
Rapides	10,417	30,916	10,889	10,417	28,430	10,889	2,487
St. Charles	-	-	1,613	-	-	1,613	-
St. James	-	311	26,917	-	-	26,917	327
St. John	-	364	7,280	-	-	7,280	315
St. Landry	24,703	84,203	7,555	24,703	78,657	7,555	5,546
St. Martin	4,585	8,111	30,828	4,585	7,339	30,828	773
St. Mary	285	3,645	43,924	285	3,298	43,924	377
Terrebonne	-	-	9,595	-	-	9,595	457
Vermilion	53,594	7,186	29,448	53,594	6,501	29,448	685
West Baton Rouge	-	5,839	14,401	-	5,283	14,401	557
Total	325,867	396,186	415,611	325,488	369,955	415,611	27,179

Optimal Processing Plant Location

Using the optimal crop mixes determined above optimal plant locations, based on minimum transportation cost for all the biomass produced. Furthermore, two different scenarios will be examined for both 2011 (Tables 4.5-4.8) and 2015 (Tables 4.9-4.12). First, one cellulosic ethanol processing facility that uses all biomass produced in the Belt. For this scenario as expected, the plant location that minimizes transportation costs is located on the Northwest periphery of the Belt. Second, scenarios for two cellulosic ethanol processing facilities demanding equal amounts of biomass are examined. The majority of energy cane production is in the Northwest and Western portions of the Belt and as expected these optimal locations are in these areas.

A potential pricing strategy that a processor could employ is a hybrid pricing strategy. Saint Landry Parish minimizes the cost of transportation, for a single processor employing a hybrid pricing strategy. In Table 4.5 are the complete parish rankings for the 22 parishes in the Belt. For a processing plant located in St. Landry, the cost is $5,763,765 to transport the 972,720 tons of biomass produced in 2011.[13] One of the key reasons for St. Landry being the low cost location is that the parish is projected to produce over 5,000 acres of energy cane. This 972,720 tons of biomass is expected to produce 24.3 million gallons of ethanol. The second lowest transportation cost parish is Acadia, which is projected to be the third largest producer of biomass.

Another option that may develop in the Belt is that multiple processors choose to locate in the region to lower the cost of transportation for bulky biomass products. For this scenario, two processing plants are considered with each receiving 486,355 tons or approximately 12.2 million gallons of ethanol. Table 4.6 shows the results for two processing plants with optimal locations for them being in Acadia and St. Landry parishes and the parishes supplying each. Furthermore, this assumes that each is employing the same hybrid pricing strategy. Under this scenario, total transportation costs drops to $4,888,538 or $875,227 less than that a single processor in the region would incur. Additionally, these parishes are neighbors and located on the western edge of the Belt and both have major interstates dissecting them allowing for easier transportation of ethanol out to the end consumers. Rapides Parish is the only one in the Belt that supplies biomass to both processors.

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[13] Assuming on average each acre of energy cane produces 35 tons.

Table 4.5: Rankings of Parish Transportation Costs for Single Processor Employing Hybrid Pricing Strategy, 2011

Rank	Parish	Transportation Cost
1	St. Landry	$5,763,765
2	Acadia	$6,367,313
3	Evangeline	$6,483,141
4	Lafayette	$6,703,742
5	Avoyelles	$7,516,107
6	Jefferson Davis	$8,277,287
7	Rapides	$8,347,928
8	Pointe Coupee	$8,359,072
9	West Baton Rouge	$8,462,668
10	Vermilion	$8,920,492
11	Iberia	$9,556,825
12	St. Martin	$9,564,541
13	Iberville	$10,566,767
14	Calcasieu	$11,053,428
15	Ascension	$11,236,285
16	St. Mary	$12,096,072
17	St. James	$12,666,622
18	Assumption	$13,169,070
19	St. John the Bapt.	$13,335,493
20	St. Charles	$14,827,106
21	Terrebonne	$15,850,457
22	Lafourche	$17,429,783

Table 4.6: Rankings of Parish Transportation Costs for Two Processors Employing Hybrid Pricing Strategy, 2011

Acadia-Plant 1		St. Landry-Plant 2	
Supplier	Amount (t)	Supplier	Amount (t)
Acadia	148,680	Assumption	3,465
Assumption	33,775	Avoyelles	168,805
Calcasieu	31,850	Rapides	78,020
Evangeline	79,730	St. John	11,025
Iberia	15,015	St. James	11,445
Jefferson Davis	56,455	St. Landry	194,110
Lafayette	21,805	West Baton Rouge	19,495
Lafourche	9,800		
Rapides	9,025		
St. Mary	13,195		
St. Martin	27,055		
Terrebonne	15,995		
Vermilion	23,975		
Total	486,355	Total	486,365

The second pricing strategy considered in this analysis is based on ethanol price. Under this strategy, a processor is expected to induce the production of 27,278 acres of energy cane or 954,730 tons of biomass, in 2011. This is 17,990 tons less biomass than is produced under a hybrid pricing strategy and expected ethanol production decreases to 23.8 million gallons. The total cost for the transportation of this biomass to the lowest cost location of St. Landry Parish is $5,570,499. Table 4.7 contains the ranking and transportation costs for the 22 parishes in the Belt to move all the biomass to a single processor. Furthermore, the parish rankings remain the same no matter whether the processor decides to employ a hybrid or ethanol pricing strategy.

Table 4.7: Rankings of Parish Transportation Costs for One Processor Employing Ethanol Pricing Strategy, 2011

Rank	Parish	Transportation Cost
1	St. Landry	$5,570,499
2	Acadia	$6,228,304
3	Evangeline	$6,302,648
4	Lafayette	$6,527,872
5	Avoyelles	$7,261,692
6	Pointe Coupee	$8,085,732
7	Rapides	$8,148,508
8	Jefferson Davis	$8,182,749
9	West Baton Rouge	$8,193,160
10	Vermilion	$8,725,319
11	Iberia	$9,311,549
12	St. Martin	$9,317,502
13	Iberville	$10,267,989
14	Ascension	$10,915,362
15	Calcasieu	$11,035,438
16	St. Mary	$11,791,826
17	St. James	$12,317,148
18	Assumption	$12,805,690
19	St. John the Bapt.	$12,970,872
20	St. Charles	$14,429,185
21	Terrebonne	$15,456,026
22	Lafourche	$17,001,243

The second scenario examined for the ethanol pricing strategy is the addition of a second processor in the Belt, with both processors employing the same ethanol pricing strategy. The advantage for the addition of a second processing facility in the region is that total transportation costs are reduced by $808, 071 to $4,762,428. Again, as with the hybrid pricing strategy the optimal location for the two plants is in Acadia and St. Landry counties. Table 4.8 contains the parishes and tons of biomass supplied to each processing facility. Overall, the two processing facilities in the region would produce approximately 11.9 million gallons of ethanol each.

Table 4.8: Rankings of Parish Transportation Costs for Two Processors Employing Ethanol Pricing Strategy, 2011

Acadia-Plant 1		St. Landry-Plant 2	
Supplier	Amount (t)	Supplier	Amount (t)
Acadia	148,680	Ascension	3,465
Assumption	33,775	Avoyelles	168,805
Calcasieu	13,860	Rapides	69,025
Evangeline	79,730	St. John	11,025
Iberia	15,015	St. James	11,445
Jefferson Davis	56,455	St. Landry	194,110
Lafayette	21,805	West Baton Rouge	19,495
Lafourche	9,800		
Rapides	18,020		
St. Mary	13,195		
St. Martin	27,055		
Terrebonne	15,995		
Vermilion	23,975		
Total	477,360	Total	477,370

Over time as biomass producers react to market signals it is important for potential processors understand how this could influence the optimal location of their processing plant. In 2015, the total costs of transportation are $5,570,499 for a single processor, which is $193,266 less than in 2011. This is a function of the decrease in energy cane acres. Energy cane acres are expected to decrease in the region as prices for other crops produced in the region increase from there expected 2011 levels. Furthermore, from a processors point of view the optimal location of the processing plant is still St. Landry Parish. Table 4.9 shows the rankings of the other 21 parishes in the Belt; the parish rankings remain the same as in 2011. Lafourche Parish is still the most expensive parish in the Belt for a processing plant and Acadia is the second best location for a processing plant. An advantage for a processor locating in St. Landry Parish would be the access to two interstates that are in close proximity. Furthermore, these interstates give a processor located in this parish the ability to ship ethanol in all directions to end users.

Table 4.9: Rankings of Parish Transportation Costs for One Processor Employing Hybrid Pricing Strategy, 2015

Rank	Parish	Transportation Cost
1	St. Landry	$5,570,499
2	Acadia	$6,228,304
3	Evangeline	$6,302,648
4	Lafayette	$6,527,872
5	Avoyelles	$7,261,692
6	Pointe Coupee	$8,085,732
7	Rapides	$8,148,508
8	Jefferson Davis	$8,182,749
9	West Baton Rouge	$8,193,160
10	Vermilion	$8,725,319
11	Iberia	$9,311,549
12	St. Martin	$9,317,502
13	Iberville	$10,267,989
14	Ascension	$10,915,362
15	Calcasieu	$11,035,438
16	St. Mary	$11,791,826
17	St. James	$12,317,148
18	Assumption	$12,805,690
19	St. John the Bapt.	$12,970,872
20	St. Charles	$14,429,185
21	Terrebonne	$15,456,026
22	Lafourche	$17,001,243

For potential processors considering locating two processing facilities in the Belt the optimal locations are Acadia and St. Landry counties, the same as in 2011. The total cost of transportation for these two facilities is reduced to $4,762,428 or $808,071 less than a single processing facility scenario. Table 4.10 shows the tons of biomass supplied and parishes supplying the biomass to the two different facilities, assuming both facilities are employing the same hybrid pricing strategy.

Table 4.10: Rankings of Parish Transportation Costs for Two Processors Employing Hybrid Pricing Strategy, 2015

Acadia-Plant 1		**St. Landry-Plant 2**	
Supplier	Amount (t)	Supplier	Amount (t)
Acadia	148,680	Assumption	3,465
Assumption	33,775	Avoyelles	168,805
Calcasieu	13,860	Rapides	69,025
Evangeline	79,730	St. John	11,025
Iberia	15,015	St. James	11,445
Jefferson Davis	56,455	St. Landry	194,110
Lafayette	21,805	West Baton Rouge	19,495
Lafourche	9,800		
Rapides	18,020		
St. Mary	13,195		
St. Martin	27,055		
Terrebonne	15,995		
Vermilion	23,975		
Total	477,360	Total	477,370

Another potential pricing strategy that processors could employ in this analysis is based upon ethanol price. For processors employing an ethanol pricing strategy it is expected that 27,179 acres of energy cane will be produced and approximately 951,265 tons that need to be transported. The cost to transport this all to a single facility located in St. Landry Parish is $5,535,637, which is 34,862 less than in 2011. Table 4.11 shows the ranking for the other 21 parishes in the Belt and from 2011 to 2015, they do not change. Furthermore, from 2011 to 2015 the ethanol pricing strategy only observes a decrease of 99 acres whereas, for the hybrid strategy the decrease 514 acres. The ethanol pricing strategy has a smaller decrease because over the time period, ethanol prices are expected to increase driving up the biomass prices producers receive and increasing transportation costs.

For the second scenario, of two processors in the region employing the same ethanol pricing strategy, the total transportation cost decreases to $4,725,075. This is an $810,562 decrease from the single processor scenario. Again, Acadia and St. Landry parishes remain the optimal locations with each receiving approximately 475,600 tons of biomass producing 11.9 million gallons of ethanol. Table 4.12 shows the tons of biomass supplied by parish and to which processing facility it is supplied. In general, the parishes supplying biomass to each of the processors remains the same from 2011 to 2015.

Table 4.11: Rankings of Parish Transportation Costs for One Processor Employing Ethanol Pricing Strategy, 2015

Rank	Parish	Transportation Cost
1	St. Landry	$5,535,637
2	Acadia	$6,187,912
3	Evangeline	$6,256,861
4	Lafayette	$6,493,686
5	Avoyelles	$7,220,888
6	Pointe Coupee	$8,055,847
7	Rapides	$8,095,023
8	Jefferson Davis	$8,132,725
9	West Baton Rouge	$8,175,596
10	Vermilion	$8,678,156
11	Iberia	$9,267,156
12	St. Martin	$9,275,392
13	Iberville	$10,251,343
14	Ascension	$10,911,897
15	Calcasieu	$10,973,626
16	St. Mary	$11,756,857
17	St. James	$12,305,402
18	Assumption	$12,787,862
19	St. John the Bapt.	$12,958,114
20	St. Charles	$14,410,010
21	Terrebonne	$15,425,981
22	Lafourche	$16,968,710

Table 4.12: Rankings of Parish Transportation Costs for Two Processors Employing Ethanol Pricing Strategy, 2015

Acadia-Plant 1		St Landry-Plant 2	
Supplier	Amount (t)	Supplier	Amount (t)
Acadia	148,680	Avoyelles	168,805
Assumption	33,755	Rapides	70,758
Calcasieu	13,860	St. John	11,025
Evangeline	79,730	St. James	11,445
Iberia	15,015	St. Landry	194,110
Jefferson Davis	56,455	West Baton Rouge	19,495
Lafayette	21,805		
Lafourche	9,800		
Rapides	16,287		
St. Mary	13,195		
St. Martin	27,055		
Terrebonne	15,995		
Vermilion	23,975		
Total	475,607	Total	475,638

Sensitivity Analysis

To this point, this paper has assumed only a 5% increase or decrease in parishes' acreages has been permitted. Furthermore, the pricing strategies investigated provide producers with lower expected net returns than sugar does. To further the investigation the constraints on acreages shifts relaxed. In this sensitivity analysis 5, 10, and 15% allowable acreages changes are considered. Furthermore, in this section the hybrid strategy is altered to so that it provides producers with approximately the same expected net return as sugar. To do this the guaranteed component of the strategy remains the same, 90%, and the second component is increased by $5.50 to $18.50 per realized ton of production. This is significantly higher than the $0.50 per ton increase required over the period 2011-2015 that makes the hybrid strategy induce the production of energy. This difference existed because this sensitivity analysis considers only one period, 2015, and for a single period to induce the production of energy cane the required increase in the second component is higher.

By relaxing the constraints on the model and allowing producers to adjust their crop allocations by more than 5% creates significant changes in the crop mix. In general, as the constraint in conjunction with the adjustment made to the hybrid pricing strategy, the production of energy cane increases significantly. This increase in energy cane production comes at the expense of soybean and rice acres. Additionally, in some parishes sugarcane acres decrease but not by as much as rice and soybean acres. Table 4.13 details these acreage shifts by parish.

Additionally, as was observed in the analysis above the majority of the energy cane is produced in the parishes on the periphery of the Belt. This is as expected, as producers residing in the parishes located in the heart of the Belt have higher expected net returns from continued sugarcane production. This even holds true once the hybrid pricing strategy has been adjust so that it is not dominated by sugarcane prices.

Furthermore, increasing the price producers receive results in the production of energy cane capable of producing between 43 and 127 million gallons of cellulosic ethanol. However, before this ethanol can be processed the biomass needs to be transported from the field to the processor. For processors to be profitable they need to do this in the most cost efficient way possible and the allocation of these energy cane acres can have a significant influences on a processors bottom line. Table 4.14 shows the parish rankings under a single processor regime in the region. For the three different scenarios, the parish rankings remained the same no matter the latitude producer had to alter their crop mix. In all scenarios, St. Landry parish is the least cost parish if a single processor was to locate in the region and institute the hybrid pricing strategy assumed in this analysis. This is not surprising given that St. Landry parish under this pricing strategy would be the second largest producer of energy cane in the region, behind only Acadia parish. As with the production of energy cane, the optimal location for a processing plant is also located on the periphery of the Belt.

Table 4.13: Optimal Crop Mix with Different Allowable Acreage Switching Assumptions

	Base (ac)			Optimal Crop Mix with 5% Switching				Optimal Crop Mix with 10% Switching				Optimal Crop Mix with 15% Switching			
Parish	Rice	Soybean	Sugarcane	Rice	Soybean	Sugarcane	Energy Cane	Rice	Soybean	Sugarcane	Energy Cane	Rice	Soybean	Sugarcane	Energy Cane
Acadia	77,607	44,603	2,089	76,135	40,355	1,890	5,919	72,439	38,231	1,791	11,838	68,744	36,107	1,691	17,757
Ascension	-	1,042	16,985	-	943	16,226	858	-	893	15,417	1,717	-	943	14,608	2,575
Assumption	-	919	35,090	-	-	35,090	965	-	-	36,055	-	-	844	36,055	1,057
Avoyelles	16,156	75,421	9,709	16,156	70,599	9,709	4,823	16,823	64,647	10,171	9,646	15,128	61,055	10,634	14,470
Calcasieu	12,126	4,165	2,790	11,642	3,769	2,790	910	10,797	3,571	2,923	1,820	9,953	3,372	3,056	2,730
Evangeline	41,588	23,911	343	40,731	21,634	343	3,135	38,717	20,495	360	6,271	36,705	19,356	376	9,406
Iberia	409	6,713	55,817	-	6,074	53,887	2,998	-	5,754	51,209	2,998	-	5,435	48,530	8,994
Iberville	-	9,718	34,346	-	8,793	33,173	2,098	-	8,330	31,537	5,996	-	7,867	29,902	6,295
Jefferson Davis	77,980	16,940	4,953	75,309	15,327	4,481	4,756	81,693	3,480	5,188	9,512	67,883	13,713	4,009	14,268
Lafayette	3,717	6,538	12,205	3,363	5,915	12,205	977	3,186	5,604	12,786	884	3,009	5,293	13,367	791
Lafourche	-	267	26,173	-	-	25,193	1,260	-	-	23,934	2,519	-	-	22,674	3,779
Pointe Coupee	2,700	65,374	32,661	2,700	60,577	32,661	4,797	2,828	56,036	32,277	9,594	2,957	52,923	30,464	14,391
Rapides	10,417	30,916	10,889	10,417	28,430	10,889	2,487	9,341	26,500	11,408	4,974	8,433	25,027	11,926	6,837
St. Charles	-	-	1,613	-	-	1,536	77	-	-	1,459	154	-	-	1,383	230
St. James	-	311	26,917	-	-	26,917	327	-	-	24,649	2,595	-	-	23,352	3,892
St. John	-	364	7,280	-	-	7,280	315	-	-	6,933	730	-	-	6,568	1,095
St. Landry	24,703	84,203	7,555	24,703	78,657	7,555	5,546	25,280	72,174	7,915	11,092	23,385	68,164	8,275	16,637
St. Martin	4,585	8,111	30,828	4,148	7,339	29,965	2,073	3,930	6,953	28,497	4,145	3,712	6,566	27,029	6,218
St. Mary	285	3,645	43,924	285	3,298	43,924	377	270	3,125	44,759	-	255	2,951	44,678	-
Terrebonne	-	-	9,595	-	-	9,595	-	-	-	9,595	-	-	-	9,595	-
Vermilion	53,594	7,186	29,448	52,787	6,501	26,643	4,297	50,235	6,159	25,241	8,593	47,682	5,817	23,839	12,890
West Baton Rouge	-	5,839	14,401	-	5,283	14,401	557	-	5,005	15,087	149	-	4,727	15,514	1,669
Total	325,867	396,186	415,611	318,376	363,494	406,353	49,552	315,539	326,957	399,191	95,227	287,846	320,160	387,525	145,981

Table 4.14: Optimal Plant Location with One Processor Employing Hybrid Pricing Strategy with Different Allowable Acreage Shifts

	Hybrid Strategey (5% Allowable Switching)		Hybrid Strategey (10% Allowable Switching)		Hybrid Strategey (15% Allowable Switching)	
Rank	Parish	Transportation Costs	Parish	Transportation Costs	Parish	Transportation Costs
1	St. Landry	$11,377,594	St. Landry	$21,862,104	St. Landry	$33,670,677
2	Acadia	$11,788,247	Acadia	$22,738,092	Acadia	$34,998,507
3	Lafayette	$11,891,432	Lafayette	$23,255,904	Lafayette	$35,476,400
4	Evangeline	$13,416,281	Evangeline	$25,519,579	Evangeline	$39,618,165
5	West Baton Rouge	$14,831,954	West Baton Rouge	$28,238,162	West Baton Rouge	$43,476,965
6	Pointe Coupee	$15,053,180	Pointe Coupee	$28,452,294	Pointe Coupee	$44,099,223
7	Vermilion	$15,108,907	Avoyelles	$28,825,867	Avoyelles	$44,776,313
8	Jefferson Davis	$15,124,052	Jefferson Davis	$29,032,526	Jefferson Davis	$44,806,973
9	Avoyelles	$15,230,937	Vermilion	$29,634,701	Vermilion	$45,021,555
10	Iberia	$16,208,480	St. Martin	$32,270,117	Iberia	$48,329,237
11	St. Martin	$16,330,149	Iberia	$32,490,433	St. Martin	$48,681,406
12	Rapides	$17,139,428	Rapides	$32,545,698	Rapides	$50,634,276
13	Iberville	$18,005,395	Iberville	$34,101,769	Iberville	$52,865,582
14	Ascension	$19,476,117	Ascension	$36,998,417	Ascension	$56,985,464
15	Calcasieu	$20,498,116	Calcasieu	$39,319,000	Calcasieu	$60,634,949
16	St. Mary	$20,894,380	St. Mary	$41,061,479	St. Mary	$62,217,606
17	St. James	$22,005,596	St. James	$41,714,969	St. James	$64,103,117
18	Assumption	$22,479,095	Assumption	$43,563,905	Assumption	$66,343,674
19	St. John the Bapt	$23,182,190	St. John the Bapt	$44,137,942	St. John the Bapt	$67,734,246
20	St. Charles	$25,494,688	St. Charles	$48,908,511	St. Charles	$74,697,702
21	Terrebonne	$27,075,714	Terrebonne	$52,432,372	Terrebonne	$79,763,085
22	Lafourche	$29,549,911	Lafourche	$57,064,479	Lafourche	$86,931,890

Table 4.15: Optimal Plant Location with Two Processors Employing Hybrid Pricing Strategy with Different Allowable Acreage Shifts (tons)

Hybrid Strategey (5% Allowable Switching)				Hybrid Strategey (10% Allowable Switching)				Hybrid Strategey (15% Allowable Switching)			
Acadia-Plant 1		**Pointe Coupee-Plant 2**		**Acadia-Plant 1**		**Pointe Coupee-Plant 2**		**Acadia-Plant 1**		**Pointe Coupee-Plant 2**	
Supplier	Amount	Supplier	Amount	Supplier	Amount	Supplier	Amount	Supplier	Amount	Supplier	Amount
Acadia	207,165	Ascension	30,030	Acadia	414,330	Ascension	60,095	Acadia	621,495	Ascension	90,125
Calcasieu	31,850	Assumption	33,775	Calcasieu	63,700	Pointe Coupee	337,610	Calcasieu	95,550	Assumption	36,995
Evangeline	109,725	Avoyelles	168,805	Evangeline	219,485	Iberville	209,860	Evangeline	329,210	Avoyelles	506,450
Iberia	104,930	Iberville	73,430	Iberia	104,930	Lafourche	88,165	Iberia	314,790	Iberville	220,325
Jefferson Davis	166,460	Lafourche	44,100	Jefferson Davis	332,920	Pointe Coupee	335,790	Jefferson Davis	499,380	Lafourche	132,265
Lafayette	34,195	Pointe Coupee	167,895	Lafayette	30,940	Rapides	174,090	Lafayette	27,685	Pointe Coupee	503,685
St. Mary	13,195	Rapides	87,045	St. Landry	54,338	St. Charles	5,390	St. Martin	215,408	Rapides	239,295
St. Martin	49,245	St. Charles	2,695	St. Martin	145,075	St. John	25,550	Vermilion	451,150	St. Charles	8,050
Vermilion	150,395	St. John	11,025	Vermilion	300,755	St. James	90,825			St. John	38,325
		St. James	11,445			St. Landry	333,882			St. James	136,220
		St. Landry	194,110			West Baton Rouge	5,210			St. Landry	582,295
		St. Martin	23,310							St. Martin	2,222
		West Baton Rouge	19,495							West Baton Rouge	58,415
Total	**867,160**	**Total**	**867,160**	**Total**	**1,666,473**	**Total**	**1,666,467**	**Total**	**2,554,668**	**Total**	**2,554,667**

The total transportation costs can be further reduced if multiple processors operate in the region. Table 4.15 shows the optimal locations and the supplying parishes to those locations if two processors operate in the region. In all three scenarios, Acadia and Pointe Coupee parishes are the optimal locations assuming they are of equal size and both are employing the same hybrid pricing strategy. In general, the suppliers to each of these plants remain the same no matter the biomass producer's ability to alter their crop allocations. For the Acadia parish plant, all of the supplying parishes are located on the western side of the Mississippi River. Whereas, parishes that supply the Pointe Coupee parish plant are on the eastern side of the river. Another advantage of locating plants in these parishes is their access to interstates and outlets for their ethanol. Specifically, interstate 10 runs through Acadia parish and provides the plant access to multiple metropolitan areas that could be potential blending point for ethanol.

Conclusions

The addition of energy cane into the portfolio of crops available for production resulted in the crop mix changing for 2011 and 2015. Furthermore, the crop mix changed differently depending upon the pricing strategy the processor(s) chose to employ. For the two different pricing strategies and time investigated the biomass production ranged between 972,720 and 951,265. Thus, making total cellulosic ethanol produced in the Belt between 24.3 and 23.7 million gallons.

For processors to induce the production of energy cane in the Louisiana Sugarcane Belt they must provide producers with pricing strategies that generate expected net returns at least equal to that they are receiving with current crops they are producing. The two pricing strategies investigated in this study are a hybrid and an ethanol pricing strategy. The hybrid pricing strategy determines the biomass price through the usage of two components. First, producers are guaranteed 90 percent of the variable cost of production. Second, producers receive $13 per ton for each realized ton of biomass production. The ethanol pricing strategy is based on the price of ethanol and the feedstock procurement percentage of cellulosic ethanol production. For the purposes of this study, it is originally set at 46 percent.

The largest portions of energy cane production come into production in the periphery parishes of the Belt. Furthermore, these parishes account for the largest portions of the current sugar industry's transportation costs, because the majority of the still-operating sugar mills are located in the heart of the Belt. Soybeans are the primary crop where acreage declines for both pricing strategies. As for rice and sugarcane, the two pricing strategies examined will need modifications to increase their expected net return if energy cane is expected to decrease acreages of these crops. Overall, the implementation of either strategy could stimulate the production of 27,000 acres of energy cane production.

The pricing strategy implemented by processors can have a significant influence on a producer's land allocation decision, and thereby change the crop mix of a region. Understanding this linkage is paramount for the development of the cellulosic ethanol industry. Without an understanding of crop mix changes, potential processors could decrease profits substantially by locating in areas were biomass is not even produced.

To minimize these transportation costs, a processor choosing to locate a single processing plant in the region should locate in St. Landry Parish. This result holds for both pricing strategies and years examined in this study. Furthermore, there would be enough biomass produced in the Belt to support approximately a 25 million gallon plant. It would cost approximately $5.5 million to transport all biomass to one location. Under a two processing plant scenario, the cost of transportation decline compared to of a single plant scenario. The optimal locations under this scenario are one plant in Acadia parish and the other in St. Landry parish, each producing approximately 12.5 million gallons. Other advantages of locating processing plants in these parishes are the interstates that dissect these parishes, which allow for easier transportation from the processor to the blender and neither parish has a sugar mill operating in the parish.

The primary drawback to the pricing strategies investigated above is that neither one currently provides producers with higher expected net returns than sugar. Therefore, a sensitivity analysis was conducted to examine what happens to crop mix and plant location, if a pricing strategy provided a producer with expected net returns that make them just as well off as producing sugar and constraints on land allocations were relaxed. By increasing the variable component of the hybrid pricing strategy from \$13.00 per ton to \$18.50 per ton producers would have an incentive to switch from sugarcane to energy cane production. This increase in price significantly increases the amount of energy cane produced and in turn the amount of cellulosic ethanol that could be produced. In general, this increase in energy cane acreage coming at the expense of rice and soybean acres. Furthermore, production of energy cane primarily takes place in the Belt's periphery parishes. This changing crop mix also influences the optimal cellulosic ethanol processing plant location. Under a single processor regime in the region, the optimal plant location remains St. Landry parish. For two processors, however, the optimal location for the plants would now be Acadia and Pointe Coupee parishes. Depending upon the land constraints imposed and the pricing strategy employed, between 43 and 127 million gallons of ethanol could potentially be produced in the Belt. The advantage of locating plants in these parishes is that they have the road infrastructure to transport biomass in and ethanol out of these plants.

Overall, the addition of new crops into the available portfolio of crops has an impact on the crop mix in the region and thus influences transportation costs. Transportation costs are a significant driver in cellulosic ethanol plant profitability. A potential processor who fails to investigate how future crop mixes in the region may shift runs the risk of locating a plant in a region that has little biomass production potential and could potentially decrease the profitability of the processor.

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CHAPTER 5: SUMMARY AND CONCLUSIONS

In order to fulfill the mandated level of 36 billion gallons of biofuel production by 2022, other sources of feedstocks, besides corn, are going to have to be employed. Corn has historically dominated the ethanol industry but given other demands on corn for feed grains, high fructose corn syrup, and exports it is not a sustainable situation even though corn could be used to meet this mandate. Another source of biofuels endorsed by EISA is cellulosic ethanol, which ethanol can be made from a wide variety of feedstocks and the type of feedstock used is driven by location and resource endowments. In Louisiana, energy cane is one of the potential feedstocks. This study examines the development of a biomass supply chain in Louisiana for energy cane.

Beginning with the producer, the first issue is that many of the potential feedstocks being considered are not traditionally grown and little is known about their production costs and practices. For energy cane, budgets are developed for two different harvest rotations. These budgets are then used to determine the various breakeven prices required, which are dependent upon energy cane yield. At current energy cane yield levels of 35 t/ac producers are going to require $30 plus per ton to breakeven. However, an inverse relationship exists, as energy cane yield increases, required biomass price decreases. If a producer, for example, could achieve a yield of 50 tons per acre, the required biomass breakeven price decreases from $30 to $22 per ton, assuming that the producer has to pay for transportation and a five-year crop cycle.

Another development in the sugar market that could significantly influence a producer’s decision on whether to produce energy cane is sugar price. In 2010, sugar prices surged to unprecedented levels in the United States. This increase in sugar price, while good for sugar producers is bad for potential cellulosic ethanol processors considering energy cane as a feedstock. Since sugarcane and energy cane are produced with the same agronomic practice and in the same region for energy cane to be produced processors need to provide producers with at least the same return as sugarcane. This is assuming that there are no additional incentives provided through federal or state programs. This will be a significant hurdle that processors considering energy cane will have to deal with as sugar prices are forecasted to be above average for the next several years. A couple of ways to possibly offset some of these increased costs, are the development of energy cane varieties that have longer crop cycles or increase the competitiveness of cellulosic with traditional ethanol.

This analysis considered the influence of increased energy cane yields as one possible solution to increase the competitiveness of cellulosic ethanol. By increasing yield, the breakeven price for biomass is driven down. In 2007, a processor considering cellulosic ethanol production with energy cane could not have been competitive, even if energy cane yields were double their current levels. By 2010, however, advancement in enzyme technologies has helped increase the competitiveness of the industry.

Once the cellulosic ethanol industry is able to solve the scaling process, it will be confronted with a new problem. How is it going to determine the price to pay producers for biomass? Early speculation is that biomass price will somehow be linked to ethanol, corn, or crude oil price. Another possibility might be a hybrid or two-tiered hybrid pricing strategy. These four strategies are examined to determine which pricing strategies in 2011, 2015, and over the time from 2011-2015 might provide producers with adequate expected returns to induce them to switch from sugarcane production into energy cane production. Under the assumptions of the initial model, none of the pricing strategies induces the production of energy cane. Minor modifications made to the ethanol and hybrid pricing strategies make them viable. For ethanol to become a viable strategy, the feedstock percentage of cellulosic ethanol production costs needs to be increased by 28% for sugarcane producers to switch to energy cane production. For the hybrid strategy to become viable either the guarantee or the variable portion of the strategy needs to be increased by 5 percent or $0.50, respectively.

From the processors perspective, they are trying to maximize profit for the firm, but also realize they must provide producers with an incentive to switch into the production of energy cane. This will most likely happen via the type of contract and pricing strategy with which the processor elects to use. Furthermore, processors know that the strategy they choose will influence the way that producers' change their crop allocation. One method with which to examine this switch crop allocation, is to examine how the two potentially viable pricing strategies influence expected returns for producers and change the land allocation in the region. If a processor wants to induce the largest acreage shift, then they would offer a hybrid pricing strategy. Under this pricing strategy 51,369 acres of energy cane are produced. The energy cane acreage could increase significantly if two changes take place. First, the constraints on the producer's flexibility to move from one crop to another are relaxed. Second, a processor(s) was willing to modify the hybrid or ethanol pricing strategy so that it provides expected net returns at least that of sugarcane.

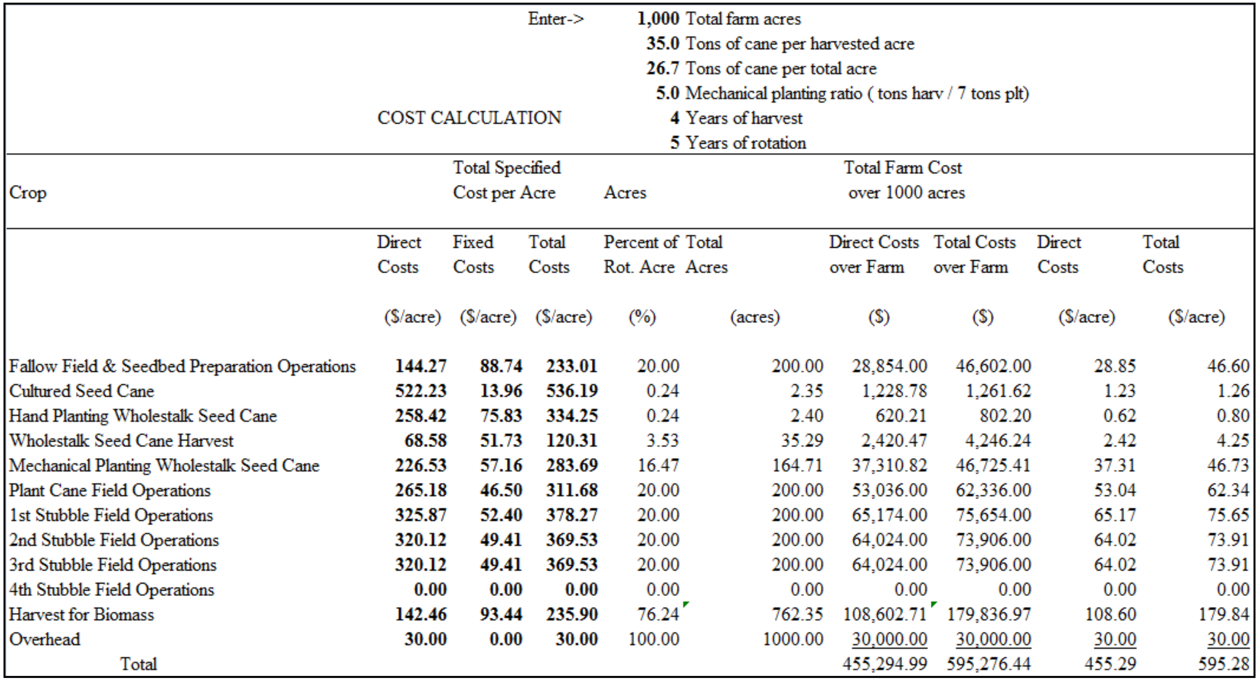
Once a processor has stimulated the production of energy cane, they must determine the transportation costs for the biomass produced. Transportation costs are a huge issue for the development of the cellulosic ethanol industry, because energy crops are bulky and expensive to transport long distances. Energy cane is 35% dry matter meaning the majority of the weight that would have to be moved is water. Consequently, a processor would want to locate close to energy cane production acreage, in order to minimize transportation costs. Furthermore, the processor also needs to know if they are going to construct one or more facilities to process the 51,369 tons of biomass. In this analysis, a single processing plant, optimally located, has transportation costs of $13 million. Increasing the number of plants from one to two, locating them optimally, would save additional $3 million per year on transportation costs.

The infancy of the cellulosic ethanol industry has generated many questions about its feasibility. This study has begun to provide answers to some of the questions. Specifically, producers can use the breakeven prices determined in this study as a beginning point for evaluating the feasibility of yields and crop length to cover all costs. This study also provides potential cellulosic ethanol processors with information about how the implementation of a hybrid pricing strategy influences the optimal crop mix in the Sugarcane Belt.

Then taking it one-step further processors can then determine how their region most efficiently produces ethanol. To help achieve energy targets each region or state within the United States should produce the type of ethanol (i.e. cellulosic or traditional) for which they have a competitive advantage. This is going to be dependent upon characteristics (e.g. crops, climate, infrastructure, etc.) of the region. Finally, stakeholders can determine how the new optimal crop mix for the region affects the siting of a new processing plant. The framework set forth can provide stakeholders with a road map to achieving regional, state, and national energy goals

APPENDIX: 3RD AND 4TH STUBBLE ENERGY CANE 2010 BUDGETS

Figure A.1: 2010 3rd Stubble Energy Cane Budget



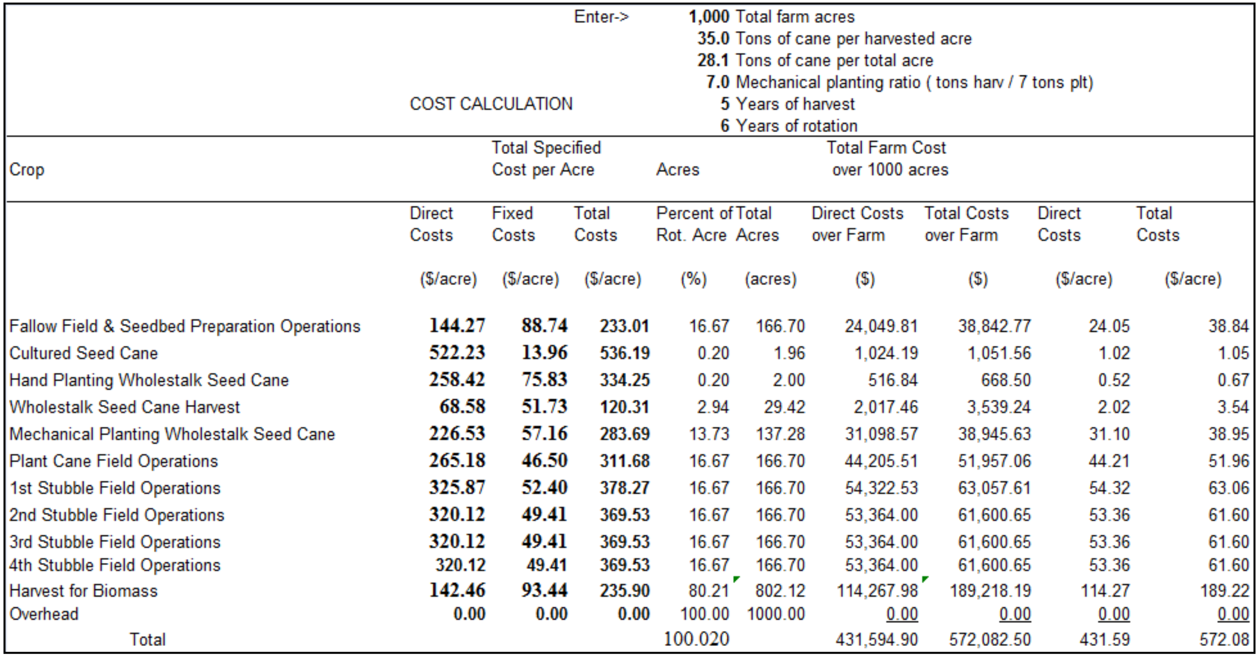
Enter->

1,000 Total farm acres
35.0 Tons of cane per harvested acre
26.7 Tons of cane per total acre
5.0 Mechanical planting ratio (tons harv / 7 tons plt)
4 Years of harvest
5 Years of rotation

COST CALCULATION

Crop	Total Specified Cost per Acre			Acres		Total Farm Cost over 1000 acres			
	Direct Costs ($/acre)	Fixed Costs ($/acre)	Total Costs ($/acre)	Percent of Rot. Acre (%)	Total Acres (acres)	Direct Costs over Farm ($)	Total Costs over Farm ($)	Direct Costs ($/acre)	Total Costs ($/acre)
Fallow Field & Seedbed Preparation Operations	**144.27**	**88.74**	**233.01**	20.00	200.00	28,854.00	46,602.00	28.85	46.60
Cultured Seed Cane	**522.23**	**13.96**	**536.19**	0.24	2.35	1,228.78	1,261.62	1.23	1.26
Hand Planting Wholestalk Seed Cane	**258.42**	**75.83**	**334.25**	0.24	2.40	620.21	802.20	0.62	0.80
Wholestalk Seed Cane Harvest	**68.58**	**51.73**	**120.31**	3.53	35.29	2,420.47	4,246.24	2.42	4.25
Mechanical Planting Wholestalk Seed Cane	**226.53**	**57.16**	**283.69**	16.47	164.71	37,310.82	46,725.41	37.31	46.73
Plant Cane Field Operations	**265.18**	**46.50**	**311.68**	20.00	200.00	53,036.00	62,336.00	53.04	62.34
1st Stubble Field Operations	**325.87**	**52.40**	**378.27**	20.00	200.00	65,174.00	75,654.00	65.17	75.65
2nd Stubble Field Operations	**320.12**	**49.41**	**369.53**	20.00	200.00	64,024.00	73,906.00	64.02	73.91
3rd Stubble Field Operations	**320.12**	**49.41**	**369.53**	20.00	200.00	64,024.00	73,906.00	64.02	73.91
4th Stubble Field Operations	**0.00**	**0.00**	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00
Harvest for Biomass	**142.46**	**93.44**	**235.90**	76.24	762.35	108,602.71	179,836.97	108.60	179.84
Overhead	**30.00**	**0.00**	**30.00**	100.00	1000.00	30,000.00	30,000.00	30.00	30.00
Total						455,294.99	595,276.44	455.29	595.28

Figure A.2.: 2010 4th Stubble Energy Cane Budget



Enter->

1,000 Total farm acres
35.0 Tons of cane per harvested acre
28.1 Tons of cane per total acre
7.0 Mechanical planting ratio (tons harv / 7 tons plt)
5 Years of harvest
6 Years of rotation

COST CALCULATION

Crop	Total Specified Cost per Acre			Acres		Total Farm Cost over 1000 acres			
	Direct Costs ($/acre)	Fixed Costs ($/acre)	Total Costs ($/acre)	Percent of Rot. Acre (%)	Total Acres (acres)	Direct Costs over Farm ($)	Total Costs over Farm ($)	Direct Costs ($/acre)	Total Costs ($/acre)
Fallow Field & Seedbed Preparation Operations	**144.27**	**88.74**	**233.01**	16.67	166.70	24,049.81	38,842.77	24.05	38.84
Cultured Seed Cane	**522.23**	**13.96**	**536.19**	0.20	1.96	1,024.19	1,051.56	1.02	1.05
Hand Planting Wholestalk Seed Cane	**258.42**	**75.83**	**334.25**	0.20	2.00	516.84	668.50	0.52	0.67
Wholestalk Seed Cane Harvest	**68.58**	**51.73**	**120.31**	2.94	29.42	2,017.46	3,539.24	2.02	3.54
Mechanical Planting Wholestalk Seed Cane	**226.53**	**57.16**	**283.69**	13.73	137.28	31,098.57	38,945.63	31.10	38.95
Plant Cane Field Operations	**265.18**	**46.50**	**311.68**	16.67	166.70	44,205.51	51,957.06	44.21	51.96
1st Stubble Field Operations	**325.87**	**52.40**	**378.27**	16.67	166.70	54,322.53	63,057.61	54.32	63.06
2nd Stubble Field Operations	**320.12**	**49.41**	**369.53**	16.67	166.70	53,364.00	61,600.65	53.36	61.60
3rd Stubble Field Operations	**320.12**	**49.41**	**369.53**	16.67	166.70	53,364.00	61,600.65	53.36	61.60
4th Stubble Field Operations	320.12	49.41	369.53	16.67	166.70	53,364.00	61,600.65	53.36	61.60
Harvest for Biomass	**142.46**	**93.44**	**235.90**	80.21	802.12	114,267.98	189,218.19	114.27	189.22
Overhead	**0.00**	**0.00**	**0.00**	100.00	1000.00	0.00	0.00	0.00	0.00
Total				100.020		431,594.90	572,082.50	431.59	572.08

VITA

Tyler is originally from Mt. Sterling, Kentucky, where he grew up on a small family farm. Upon completion of high school in 2000, he attended the University of Kentucky and graduated four years later with Bachelor of Science in agricultural economics. From there he chose to continue his education at Purdue University where he completed his Master of Science in agricultural economics in May of 2006. After taking the summer off from research and classes, he decided to attend Louisiana State University and begin the pursuit of a Doctorate in agricultural economics.

During his academic career at Louisiana State University, he has authored or coauthored five peer reviewed journal articles, two extension publications, and given numerous presentations and posters. Currently the majority of his research is focused on biofuels including energy cane, switchgrass, and sweet sorghum. These potential energy crops are being considered for use in the production of biomass for cellulosic ethanol production. Specifically, his dissertation conducts an in-depth examination of the production costs, potential pricing strategies, optimal crop mix, and optimal plant locations to determine the feasibility of producing cellulosic ethanol in the Louisiana Sugarcane Belt. His other research interests include expectations of government payments by producers; linkage between direct marketing and income for producers; costs of conducting on-farm research for producers; and shopping habits of Millennials.

Additionally during his time at Louisiana State University, he has had the opportunity serve as President of the Agricultural Economics Graduate Student Association for two consecutive terms and helped to improve the visibility of the graduate students within the department and profession. At the national level, he also served as the Member-at-Large for Activities in the Applied Agricultural Economics Association Graduate Student Society.

He will be graduating from Louisiana State University in December of 2010. However, in August of 2010 he will begin an Assistant Professor position at Morehead State University where he will teach agricultural economics.