ECONOMIC FEASIBILITY OF ETHANOL PRODUCTION FROM SWEET SORGHUM JUICE IN TEXAS

A Thesis

by

BRITTANY DANIELLE MORRIS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2008

Major Subject: Agricultural Economics

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Approved by:

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ABSTRACT

Economic Feasibility of Ethanol Production from Sweet Sorghum Juice in Texas.
(December 2008)
Brittany Danielle Morris, B.S., Texas A&M University
Chair of Advisory Committee: Dr. James W. Richardson

Environmental and political concerns centered on energy use from gasoline have led to a great deal of research on ethanol production. The goal of this thesis is to determine if it is profitable to produce ethanol in Texas using sweet sorghum juice.

Four different areas, Moore, Hill, Willacy, and Wharton Counties, using two feedstock alternatives, sweet sorghum only and sweet sorghum and corn, will be analyzed using Monte Carlo simulation to determine the probability of economic success. Economic returns to the farmers in the form of a contract price for the average sweet sorghum yield per acre in each study area and to the ethanol plant buying sweet sorghum at the contract price will be simulated and ranked.

The calculated sweet sorghum contract prices offered to farmers are $9.94, $11.44, $29.98, and $36.21 per ton in Wharton, Willacy, Moore, and Hill Counties, respectively. The contract prices are equal to the next most profitable crop returns or ten percent more than the total cost to produce sweet sorghum in the study area. The wide variation in the price is due to competing crop returns and the sweet sorghum growing season.

Ethanol production using sweet sorghum and corn is the most profitable alternative analyzed for an ethanol plant. A Moore County ethanol plant has the highest average net present value of $492.39 million and is most preferred overall when using sweet sorghum and corn to produce ethanol. Sweet sorghum ethanol production is most profitable in Willacy County but is not economically successful with an average net present value of $-11.06 million. Ethanol production in Hill County is least preferred with an average net present value of $-712.00 and $48.40 million when using sweet sorghum only and sweet sorghum and corn, respectively.

Producing unsubsidized ethanol from sweet sorghum juice alone is not profitable in Texas. Sweet sorghum ethanol supplemented by grain is more economical but would not be as profitable as producing ethanol from only grain in the Texas Panhandle. Farmers profit on average from contract prices for sweet sorghum when prices cover total production costs for the crop.

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CHAPTER I

INTRODUCTION

Ethanol was considered an optimistic venture to replace fossil fuels in the 1970s. The oil embargo by the Organization of the Petroleum Exporting Countries (OPEC) caused oil supplies to decrease and oil and gasoline prices to increase rapidly. With the United States (U.S.) being put into a very vulnerable position, interest turned to producing ethanol.

Between 1979 and 1983, ethanol production rose sharply from 20 to 385 million gallons per year (Hanson 1985). The 1973 embargo's failure lowered oil prices on the world market, which further slowed the demand for, and therefore the production of ethanol. The drought in 1988 reduced the available feedstock for the ethanol industry, which led to higher costs and further reduced production of ethanol.

Environmental and health concerns aided the continuation of ethanol production. Leaded gasoline was used to prevent knocking in engines since the 1920s, but later was cited as a possible health risk that could cause severe damage to the nervous system and brain function. The first lead reduction mandates were issued in the 1970s, with the complete phase out of lead in commercial cars in 1996 (US/EPA 1996). Lead has since been replaced by ethanol in gasoline to stop engine knocking (US/EPA 1996).

This thesis follows the style of the *American Journal of Agricultural Economics.*

The Clean Air Act of 1990 mandated that oxygenates and reformulated gasoline be used in certain parts of the country during specific seasons such as summer and winter. Both ethanol and methyl tert-butyl ether (MTBE) are used as oxygenates (Nalley and Hudson 2003). The use of MTBE is currently being phased out as an oxygenate nationally as specified in the Energy Policy Act of 2005 due to concerns over water pollution from MTBE. The phase out has encouraged ethanol production to supplement gasoline to reduce harmful environmental impacts.

Ethanol can be made from many feedstocks. Brazil has been successful at utilizing sugarcane juice to make ethanol since the 1970s. The United States has primarily used corn for ethanol production, but grain sorghum is used on a smaller scale in some areas. There is increasing interest in using sweet sorghum juice as an ethanol feedstock in the United States.

Corn was initially considered to be the feedstock of choice for ethanol. Ethanol plants have predominately been located in the Midwest where a majority of U.S. corn is grown. These refineries can achieve lower costs of production because the cost of corn is lower in the Midwest due to the large corn supply. However, corn is used heavily in the food and livestock sectors with large quantities exported. Because of the increased demand for corn by ethanol plants, the price of corn has drastically increased to some of the highest prices in U.S. history. Farmers are responding to high corn prices by shifting planted acres to corn (Sauser 2007; NASS 2007; Whetstone 2007). Shifting crop acres increased other grain prices as well.

The livestock and human food industries have also experienced rising costs. Field corn is fed to livestock such as poultry, pigs, and cattle. Higher corn prices have increased the costs of producing animal products such as meat and milk. There have been conflicting opinions regarding the cause of increased food prices. The National Corn Growers Association (NCGA) maintains that sweet corn, which is consumed by humans, is not used for ethanol production and thus cannot be the reason why food prices have increased (NCGA 2007). Outlaw et al. (2007) reported that thus far the data do not statistically support the hypothesis that high corn prices have led to high food prices. However, other publications blame ethanol for rising food prices. Muhammad (2007) and Sauser (2007) report that food prices have risen because of increased demand for corn to produce ethanol.

Increased corn acres may come with other costs. The effects of more water, chemical, and fertilizer used to grow corn has caused concern for the environment. Some researchers and environmentalists assert that because corn requires more water, chemicals, and fertilizers than other crops, more water sources could possibly be depleted and polluted because of excessive use and runoff (Blottnitz and Curran 2007; Pimentel and Patzek 2005; Nalley and Hudson 2003; Pimentel 2003; Pimentel 1991).

Ethanol production is more economically feasible now due to higher gasoline prices (Shapouri, Salassi, and Fairbanks 2006). A great deal of research has been done on biomass ethanol, yet cellulosic conversion technology is not commercially available. According to Outlaw et. al. (2007), sugarcane juice ethanol, like that produced in Brazil, would be economically feasible; however, the United States does not grow much sugarcane. A crop similar to sugarcane that can be grown in numerous places in the United States is sweet sorghum. Sweet sorghum juice is a feedstock that may be feasible for ethanol production (Venturi and Venturi 2003).

The objective of this research is to determine the economic feasibility of using sweet sorghum juice to produce ethanol in Texas. The methods used to harvest, squeeze, and transport the sweet sorghum will have a direct impact on the feasibility of using this feedstock for ethanol production. The analysis will focus on the cost to produce sweet sorghum for juice in Moore, Hill, Wharton, and Willacy Counties in comparison to the competing crops in production and on the potential profits to ethanol producers.

This study is organized into eight chapters. The introduction completes Chapter I. Chapter II reviews the literature concerning ethanol, ethanol production feasibility, ethanol production in the rest of the world, sugar to ethanol, steam and electricity generation using bagasse, sweet sorghum, and simulation and ranking of risky alternatives. Chapter III describes the method used, followed by the description of the model in Chapter IV. The parameters and model validation tests are presented in Chapter V. Chapters VI and VII detail the farm model and ethanol model results, respectively. The final chapter provides the summary and concluding remarks.

CHAPTER II

LITERATURE REVIEW

Research has been conducted on different aspects of the ethanol industry but there has not been a study over the use of sweet sorghum juice for ethanol production in the United States or Texas. The review of literature provides an overview of previous literature on the U.S. ethanol industry, ethanol production in the rest of the world, sugar to ethanol, steam and electricity generation using bagasse, sweet sorghum, and simulation and ranking of risky alternatives.

Ethanol

Ethanol production in the United States comes largely from corn. There were 162 ethanol plants in operation as of July 2008 with a production capacity of 13.6 billion gallons per year (RFA 2007). Forty-one new ethanol refineries were under construction halfway through 2008. Over 97% of the nation's ethanol supply is produced using corn.

United States ethanol use was 5.4 billion gallons in 2006 (Renewable Fuels Association 2007). To satisfy this demand, over 653 million gallons were imported to supplement domestic production. The Department of Energy reported that in 2004, biomass energy consumption of 2.845 quadrillion British thermal units (Btus) made up about 3% of total energy consumed. Fossil fuels made up approximately 86% of energy consumed.

Ethanol as an energy source will not replace all fossil fuels (Renewable Fuels Association 2007). Energy sources such as coal, wind energy, petroleum, natural gas, and others are used for transportation fuel or to produce electricity. Only those liquid fuels that are used in some vehicles could be offset by ethanol. Producing ethanol from sweet sorghum results in by-products such as bagasse which could be used to produce electricity.

Ethanol Production Feasibility Studies

English, Short, and Heady (1981) analyzed the feasibility of using crop residues for direct combustion in Iowa's electrical generating power plants. Using a profit maximizing linear programming model, the study found that energy use, with the exception of coal, increased slightly with the removal of residues. For instance, the energy used for diesel, natural gas, electricity, and liquid petroleum gas increased from 90.9 trillion Btu's at zero percent use of crop residues to 99.4 trillion Btu's at a 60% substitution of crop residues for coal. Total energy use from coal decreased far more than the increase in other energy sources. Energy from using coal decreased from 118 to 47 trillion Btu's when crop residues were substituted at a rate of zero percent to 60% for coal, respectively. More non-coal energy was required by the agriculture sector to collect the crop residues because more machinery and man hours were needed to harvest the stalks and leaves. A greater decrease in coal use was attributed to residue utilization in power plants. English, Short, and Heady concluded that burning crop residues might be feasible when faced with rapidly rising energy prices such as those seen in 1978-1979.

A study done by Hanson (1985) analyzed the financial feasibility of producing corn ethanol in a co-generation plant in Alabama. It was determined that ethanol co-generation was financially feasible on a net present value basis even though the first three years of operation did incur losses ranging from $46.3 million to $0.8 million. Ethanol production without cogeneration was not economically feasible. High corn prices ($4.16 per bushel) and operating at half capacity were reported to delay payback by two and 2.4 years. The study failed to incorporate risk.

Kaylen et al. (2000) used a non-linear optimization General Algebraic Modeling System (GAMS) model to determine the feasibility of a lignocellulosic biomass plant in Missouri. The model reported that transportation costs were approximately $44.8 million for 1.44 million tons of feedstock annually, or $31.10 per ton. Net present value for fifteen years was positive at $176.9 million when furfural, a liquid chemical byproduct of agriculture waste, was co-produced with ethanol. The study concluded that energy crops were the least desirable feedstocks based on their high per unit cost and high lignin and low hemi-cellulose content. Kaylen et al. also reported that ethanol would need to be coproduced with another material, such as furfural, to be economically feasible when using lignocellulosic materials. The study used a very conservative model approach, so estimates may not be an accurate representation of Missouri counties or energy crop feasibility.

Herbst (2003) analyzed the economic feasibility of ethanol plants in three different regions of Texas using grain sorghum or corn as feedstocks. Risk was accounted for by using stochastic simulation that allowed input and output prices to fluctuate based on their historical variability. Plant sizes of 20, 40, 60, and 80 million gallons per year (MMGY) of ethanol output were assumed. An 80 MMGY grain sorghum ethanol plant in the Texas Panhandle had the highest chance of positive net present value (NPV) between 2003 and 2018.

Grain sorghum ethanol plants in the Panhandle and Central Texas had positive net income over the 15 years simulated (Herbst 2003). The probability of positive net income was high initially, dropped off between 2004 and 2011, and then became fairly steady after 2011. Projected average net income for an 80 MMGY facility in the Texas Panhandle was approximately $11 million by the third year with over an 80% probability of positive net income. The probability of positive net income decreased from 80 to 60% from the third to eighth year. Following the eighth year, the probability of positive net income was then projected to remain between 60 and 70% for the remaining seven years in the simulation. Different capacity scenarios for grain sorghum in the Panhandle followed a similar path yet had different net income expectations and positive probabilities. An 80 MMGY plant using grain sorghum in Central Texas reported more risk on net income than the Panhandle facility.

The analysis of grain sorghum ethanol production in Southeast Texas did not generate profitable results based on annual net income or the probability of positive annual net income (Herbst 2003). Higher sorghum prices in Southeast Texas increased production costs for an ethanol plant in the area. Average net income for the 20, 40, and 60 MMGY plants was negative. The probability for positive net income decreased to about 30% for the 40, 60, and 80 MMGY plants and only 15% for the 20 MMGY plant by 2018.

Shapouri, Salassi, and Fairbanks (2006) researched the feasibility of producing ethanol using sugar from a variety of crops. Findings in the study indicated that with the price of ethanol around $4 per gallon, sugarcane, sugar beets, raw sugar, and refined sugar could all yield a profit when used as a feedstock. If the price of ethanol dropped to $2.40 per gallon, raw and refined sugar did not generate positive profits. Their study did not consider using sugarcane juice as a feedstock even though it is much cheaper than using raw sugar. Risk was not considered in their study.

Outlaw et al. (2007) analyzed the economic feasibility of integrating ethanol production from sugarcane juice into existing sugar mills in the United States. The results, based on a probabilistic Monte Carlo financial statement model, determined that positive net cash income was generated each year and there was a 100% chance of positive net present value over a ten year period for a 40 MMGY plant. The NPV over 10 years ranged between $4.7 and $90.4 million when sugarcane producers received $17 per ton of sugarcane and the average ethanol price was $2.00 per gallon. These results included government ethanol subsidies. If these subsidies were excluded, ethanol production from sugarcane juice would not be feasible.

Ribera et al. (2007a) analyzed the feasibility of integrating an ethanol production facility into an existing sugarcane mill in the United States using Monte Carlo simulation. The economic benefits of operating a sugar/ethanol mill that makes sugar from sugarcane and ethanol from sugarcane juice and molasses were analyzed. The study concluded that there was an 81.6% chance of positive NPV for a 35 MMGY sugar/ethanol mill when ethanol price was $1.87 per gallon. The sugarcane cost was approximately $0.91 per gallon of ethanol produced. The NPV increased considerably from $77.8 million for a sugar mill to over $131 million by adding an ethanol production facility to the mill. The NPV for a sugar/ethanol mill varied more as indicated by a standard deviation of $22,245,086 compared to the sugar mill standard deviation of $12,333,521. The study determined that the sugar/ethanol mill would be preferred and have a higher probability of economic success over a sugar mill based on results for: net present value, annual net cash income, and annual cash flows.

Ribera et al. (2007b) evaluated the economic feasibility of using a non-feed crop such as sugarcane (juice) along with grain for ethanol production using Monte Carlo simulation. The study assumed that the plant produced 100 million gallons of ethanol per year. Half of the ethanol would be produced with sugarcane juice, while the other half would come from grain sorghum or corn. The study determined that the cost of producing sugarcane and sorghum ethanol would be $1.92 and $1.88 per gallon, respectively. Based on current prices and costs, $3.50 per bushel for sorghum, and $2.00 per gallon for ethanol, the average NPV would be $78.7 million with a 97.5% chance of making greater than a 15% return on initial wealth. The NPV varied from approximately $-58 million to $200 million over 10 years.

The best method for economic feasibility analysis is Monte Carlo simulation because it gives the probability of success, probability of positive returns, and ending cash reserves. These three variables help stakeholders make a decision based on probabilities instead of worst, best, and average estimated outcomes.

Economics of Biomass Production

Goodman (1991) focused on land erosion and the financial performance of three different locations with a variety of crops and switchgrass for producing ethanol. Two representative farms in Tennessee and one in Georgia were used in the study. The Micro-Oriented Agricultural Production Simulator (MOAPS) was used to simulate the farm financial performance for a ten year period. The findings showed that farms which produced switchgrass to be sold as an energy crop received a return comparable to (or higher than) enrolling the same land in the Conservation Reserve Program (CRP). Despite the decrease in net farm income over ten years, all farms benefited financially more under the switchgrass plan than the historical crop mix. The switchgrass price was reported to be $36.28 per ton in 1986 dollars. The assumption that the price for switchgrass followed the general rate of inflation may have given a biased output in favor of switchgrass production instead of enrollment in the conservation program. This study did not include risk in the model.

Reese et al. (1993) determined that the agricultural economy could benefit as a whole from a large biomass industry by producing and selling grassy energy crops to ethanol producers. An applied general equilibrium model, basic linked system, simulated the world agricultural economy from 1990 to 2030 under high and low biomass production scenarios. The results showed increased prices for feed grains due to shifting acres to grassy crops for ethanol. Higher feed grain prices caused livestock producers to have higher costs of production. Livestock producer losses would be offset by gains from traditional and grassy crop producers leading to an overall benefit to the agriculture industry. Also, government payments would decrease due to increased crop prices. However, the basic linked system simulated the status quo in 1990 until 2030 for the base scenario and disregarded risk; therefore, unexpected changes in variables, such as fuel costs seen in recent years, will likely make the findings less accurate. Baseline scenario projections were not detailed in the report.

Epplin (1996) estimated the transportation and production costs for switchgrass, but did not continue the study to the economic feasibility of the ethanol plant. A standard enterprise budgeting model was used to estimate results for the cost of establishing switchgrass on cropland within 50 miles of the ethanol plant in Oklahoma and the cost of maintaining and harvesting an established switchgrass stand. Results showed transportation costs from the field to the ethanol plant amounted to $120 per load (12.3 tons) or $9.70 per ton. The cost to establish a switchgrass stand was calculated to be approximately $120.39 per acre including land rent, fixed machinery cost, and operating costs. Maintaining the crop would cost $87.80 per acre. Risk was not included in Epplin’s study so the costs provided are presumably means.

Estimates of switchgrass farmgate prices, land rent for cropland, marginal delivered price, and average transport costs in Tennessee are provided by Graham, English, and Noon (2000). The study found that the price paid to farmers before transportation costs for switchgrass ranged between $24.73 and $30.75 per ton. The marginal delivery prices were estimated to be between $33.57 and $37.45 per ton for the various study areas. Graham, English, and Noon also found that the average transportation costs ranged from $5.10 to $7.67 per ton depending on annual energy crop supply of the area and its distance from a specified destination.

Mapemba et al. (2007) estimated the costs associated with producing biomass (grass) on conservation reserve program (CRP) land in Oklahoma using various scenarios for production months, harvest dates, and refinery capacities. Three policy scenarios that specified the number of days and percent of CRP acreage available for harvest were evaluated for three different plant capacities. Plant capacity was set at 1,000, 2,000, and 4,000 tons per day for full capacity. The model was able to determine the total cost of delivered feedstock ranged from $25.70 to $57.83 per ton depending on the production month, harvest dates, and refinery capacity. Harvest and transportation costs were also broken down to show a range of $9.87 to $30.10 and $7.44 to $19.34 per ton, respectively. Results might be skewed because the study only included CRP land. Dollar amounts for input costs, such as diesel, were not specified in the report.

The studies done by Epplin (1996), Graham, English, and Noon (2000), and Mapemba et al. (2007) provide estimated transportation, harvest, and feedstock cost ranges. Epplin (1996) reported transportation costs of $9.70 per ton of switchgrass. In the study by Mapemba et al. (2007) transportation costs ranged from $7.44 to $19.34 per ton, harvest costs were between $9.87 and $30.10 per ton, and the total cost of delivered feedstock ranged from $25.70 to $57.83 per ton. Graham, English, and Noon's (2000) study estimated average transportation costs ranged from $5.10 to $7.67 per ton, marginal delivery prices were between $33.57 and $37.45 per ton, and the cost of feedstock before transportation costs ranged from $24.73 to $30.75 per ton.

Ethanol Production in the Rest of the World

There are a number of scientists who have conducted studies on sorghum for energy. Researchers at the Nimbkar Agriculture Research Institute in the Indian State of Maharashtra, the Food and Agriculture Organization of the United Nations, International Crops Research Institute for the Semi-Arid Tropics in India, Philippine Department of Agriculture, and other entities have reported on their work with sorghum.

Europe

Monti and Venturi (2002) compared the net energy efficiency of fiber sorghum, sweet sorghum, and wheat at two different nitrogen levels for ethanol production in Bologna, Italy. Energy amounts for production inputs such as machinery and fertilizer were estimated and used to determine the net energy of each crop. Sweet sorghum performed better than fiber sorghum, low nitrogen wheat, and high nitrogen wheat stands by 14, 38, and 26%, respectively, in net energy output. The analysis did not report the costs to produce these crops.

Venturi and Venturi (2003) compared the feasibility of using wheat, barley, maize, grain sorghum, sugarbeet, sweet sorghum, and Jerusalem artichoke as alternative fuel feedstocks in Northern, Central, and Southern Europe. There were up to 34 countries assessed for the crops in the model. The results showed that sweet sorghum may be a potential feedstock in the future due to its photosynthetic efficiency and energy balance. However, sweet sorghum will only be feasible if agriculture practices become more energy efficient and sweet sorghum seeds are made widely available. The results from the study were based on test plot data for sweet sorghum, therefore the feasibility of using sweet sorghum for ethanol production may not be accurate under actual farming practices. It was considered a good option for ethanol production because of its photosynthetic efficiency and net energy balance, which was approximately 15-20 GJ per hectare (Venturi and Venturi 2003).

Africa

Richardson, Lemmer, and Outlaw (2007b) quantified the risks and economic prospects that influence the profitability of bio-ethanol production from wheat in the winter rainfall region of South Africa using Monte Carlo simulation. The study concluded that the base scenario had a 97% chance of negative net present value (NPV) when a plant produced 27.21 million gallons of ethanol annually. The average NPV was –$13.07 million. The base scenario assumed an accelerated depreciation method, use of a bio-ethanol marker as a denaturant, 50% shared financing, 95% of the Basic Fuel Price (BFP) formula for the ethanol price, and 31.5% reimbursement on the fuel levy. Adding a $0.58 per gallon subsidy to the base decreased the probability of economic failure to 0.5% with an average NPV of $11.4 million. Pricing bio-ethanol at 100% of the BFP plus 100% reimbursement on the fuel levy yielded an estimated average NPV over $11.8 million and the probability of negative NPV declined to 0.5%. An inflation adjusted price floor at $1.86 per gallon increased NPV from the base scenario even though it was less than the subsidy. The fifth pricing option included a price floor of $1.86 per gallon in the base scenario and increased the reimbursement on the fuel levy to 70%. Option five had the greatest economic benefits yielding an average NPV of $14.84 million and a 100% chance of positive NPV.

Brazil

After the OPEC embargoes in the 1970s, the Brazilian government created the National Alcohol Program, otherwise known as ProAlcool. The primary goal of ProAlcool was to reduce dependency on foreign oil, but the program also successfully developed the industrial and agriculture sectors, increased employment and thereby the socio-economic status of rural areas. From 1975 until 2006, Brazil was the leading producer of ethanol (Renewable Fuels Association 2007). Production in 2005 was at 4.2 billion gallons per year (BGY) and 4.5 BGY in 2006. The United States produced slightly more than Brazil for the first time in 2006 at 4.9 BGY. Ethanol production from sugarcane juice has increased with technology and advancements in farming since the inception of ProAlcool (Rosillo-Calle and Cortez 1998).

Heavy government involvement and regulations made the ethanol industry expand initially (Hall, Rosillo-Calle, and de Groot 1992). In 1991, ProAlcool was replaced by the Alcohol Interministerial Committee (CIMA). The CIMA sets ethanol prices in Brazil (Bolling and Suarez 2001; Goldemberg et al. 2004; Rosillo-Calle and Cortez 1998). Until 1994, prices had been unified across the country, meaning that despite different geographic locations, the price was the same. Prices have been non-unified since 1994 (Rosillo-Calle and Cortez 1998). The industry changed further in May 1997 and February 1999 when anhydrated and hydrated ethanol prices were liberalized, respectively. Today, there are no longer subsidies for ethanol producers in Brazil (Goldemberg et al. 2004; Rosillo-Calle and Cortez 1991).

Even though Brazil has been credited with having a successful ethanol program, it is not likely to be replicated in the United States (Rothman, Greenshields, and Rosillo-Calle 1983). Wage rates are much lower in Brazil leading to lower costs of production. Because Brazil is a leading producer in the sugar market, ethanol production and price is contingent on the price of sugar. If sugar prices are high, more sugarcane will be dedicated to sugar production instead of ethanol (Bolling and Suarez 2001). The U.S. sugar industry is much smaller than Brazil's and has limited potential for expansion.

The feasibility of sugar based ethanol in the United States has been investigated by only a few researchers. Shapouri, Salassi, and Fairbanks (2006) reported that the cost to produce ethanol using sugarcane sugar, not juice, as a feedstock is more than double the cost of using corn as a feedstock, but at $4.00 per gallon of ethanol, sugarcane would still be profitable to use for ethanol. Outlaw et al. (2007), Ribera et al. (2007a), and Ribera et al. (2007b) used Monte Carlo simulation to determine that sugarcane could be a profitable feedstock for ethanol production under certain conditions such as coproduction of sugar or continued government subsidies for ethanol refineries.

Sugar to Ethanol

The United States has traditionally converted the starch in corn to sugar by adding water and enzymes. This process, known as hydrolysis, breaks down the cellulose and hemicellulose that is in grain into glucose and xylose, respectively (Murphy and McCarthy 2004). The sugars are then fermented and distilled to produce ethanol. From 2.65 to 2.75 gallons of ethanol can be produced per bushel of corn (Salassi 2007).

Using the juice from a sugar crop as the ethanol feedstock allows the refinery to skip the hydrolysis phase (Jacobs 2006; Gnansounou, Dauriat, and Wyman 2005). When the plant stalks are delivered to the refinery, they are squeezed, separating the juice from the plant material. The juice is then fermented and distilled into ethanol. The actual recoverable amount of ethanol from one ton of sucrose is 141 gallons, theoretically (Salassi 2007).

Steam and Electricity Generation Using Bagasse

Bagasse is the remaining plant material after the juice has been squeezed from the stalks. The byproduct can be used to produce electricity and steam for the refinery or for sale on the electricity grid (Jacobs 2006; Gnansounou, Dauriat, and Wyman 2005). It is uncommon for sugar mills in Brazil to use the bagasse for energy to decrease operating costs and to produce electricity for sale.

Despite the added benefits of burning bagasse for steam and electricity, the capital expenses for the boiler and turbocharger are high. The National Renewable Energy Laboratory (NREL) reported boiler costs that ranged from $19.8 to $24.9 million and varied with pressure and temperature (McAloon et al. 2000). A later study reported boiler and turbogenerator costs at $37.5 million under unspecified operating capacities (Aden et al. 2002). The projected cost of two boilers in a 40 MMGY sugarcane/ethanol plant is approximately $30 million (Dedini 2007).

Sweet Sorghum

There are several varieties of sweet sorghum. They range in size, yield, and use. The Mississippi Agricultural and Forestry Experiment Station (MAFES) and the United States Department of Agriculture (USDA) developed several sweet sorghum varieties. The four varieties that were developed, Dale (1970), Theis (1974), M81-E (1981), and Topper 76-6 (1994), have different maturity lengths, seed weights, juice and dry matter yields, and physical features. At Texas A&M University, Rooney and Blumenthal are testing hybrid sweet sorghums for biomass and energy production. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is developing new sorghum varieties specifically for ethanol production.

Sweet sorghum is in the same family as sugarcane but can thrive in drier and cooler locations. During very dry periods, sweet sorghum can go into dormancy, yet will start to grow when moisture returns (Gnansounou, Dauriat, and Wyman 2005). The crop does not require as much fertilizer or chemicals as corn. Less fertilizer and chemical use could alleviate some environmental concerns and reduce production costs. Sweet sorghum can produce juice that is suitable for conversion into ethanol. Additionally, the bagasse can be used to generate electricity or energy (Blottnitz and Curran 2007; Gnansounou, Dauriat, and Wyman 2005; Monti and Venturi 2002).

Sweet sorghum can be grown in the same areas as grain and forage sorghum, mainly Kansas, Nebraska, and Texas (NASS 2007). Grain sorghum production in 2007 for all uses was 504.9 million bushels on 7.7 million planted acres. Production in 2007 was just slightly above that for 2004, 2005, and 2006. Sorghum harvested for silage increased by 50 thousand acres in 2006 and 2007. The increased demand for feed grains for ethanol and poor weather conditions in 2005 drove sorghum and other crop prices up (Whetstone 2007). Grain sorghum prices rose from $3.33 per hundred weight (cwt) in 2005 to $5.88 in 2006 and $6.90 in December 2007 (NASS 2007).

The possible growing area in the United States makes sweet sorghum a potentially viable energy crop. Because sweet sorghum can be used as either an energy crop or sold as forage for livestock, sweet sorghum has different markets that make it more secure for farmers to grow versus biomass crops that will only have one market option.

Economic Study of Sweet Sorghum for Ethanol

Worley, Vaughan, and Cundiff (1992) examined the energy costs for producing sweet sorghum for ethanol production in Virginia. The harvesting system consisted of harvesting the sweet sorghum stalks, transferring them to a field-side press, and squeezing the juice from the stalks. The juice was captured in a tank to be transported to an evaporation and storage facility or sent to the distillery. The bagasse was ensiled close to where it was cut and used as livestock feed. Transportation distances to the evaporation and storage facility were 9.94 miles and another 29.83 miles to the distillery. Energy balances were 0.91 and 0.84 for juice ethanol and corn ethanol when considering the quantity of both liquid and non-liquid fuels used to produce ethanol. Energy balances, or the difference between the energy used and the energy generated, were higher at 3.54 and 4.52 for sweet sorghum juice and corn ethanol when only accounting for the liquid fuel used to make ethanol. Worley, Vaughan, and Cundiff (1992) estimated that 153 gallons of ethanol per acre could be produced from sweet sorghum juice compared to 260 gallons from corn; however, sweet sorghum juice ethanol required fewer overall inputs than corn ethanol regardless of the type of fuel (liquid or non-liquid) that was included in the calculations.

Simulation and Ranking Risky Decisions

Uncertainty and risk are inherent in most ventures, however, they are not interchangeable and are unique to various businesses. Uncertainty is imperfect knowledge, while risk is defined as uncertain consequences, particularly exposure to unfavorable consequences (Hardaker et al. 2004a, p. 5). Roberts, Osteen, and Soule (2004) add that uncertainty does not have an estimated probability of an event occurring but risk does. Uncertainty and risk are a large part of decision making in any business. Stakeholders can choose the best perceived option at their preferred risk aversion and profit level. Quantitative methods have been developed and used to help decision makers make from various risky alternatives.

Sources of Risk

Agriculture often is thought to be riskier than other businesses, such as manufacturing, based on the variables that affect success in agriculture. Crop yield risk is typically the main variable that sets agriculture apart from other industries because it deals with living organisms, but price risk and political forces also make farming riskier than most industries (Hardaker et al. 2004a, p. 6; Roberts, Osteen, and Soule 2004).

Crop yield is a variable that directly determines farming success, and the risk attached to it is exclusive to agriculture in a variety of ways (Hardaker et al. 2004a, p. 6). Weather has a drastic affect on crop yields and often is not controlled or offset by farming practices. This is not so for industries that operate in an environmentally controlled building. Pests in the form of insects, harmful animals, and disease can be avoided to some extent with strategic planning and action on the farmer's part, but still add risk to crop yield.

Furthermore, changing prices are partly responsible for net income risk incurred by farmers. Prices received for crops and prices paid for inputs are not controlled by farmers. When crop prices decrease or input prices rise, it increases the risk of making positive profits (Hardaker et al. 2004a, p. 6).

Political forces play a role in all businesses, yet a large amount of government support and regulation affect the decisions made on farms (Hardaker et al. 2004a, p. 6). United States policy on biofuels has encouraged ethanol production, which has led to higher grain prices. Removal of ethanol subsidies could lead to lower grain prices, increasing farmers' and ethanol producers' income risk.

Ethanol price is determined mainly by feedstock supply and costs, ethanol demand, and government subsidies and regulations. Because gasoline is used to denature ethanol, the price of gasoline also affects ethanol prices. Ethanol prices have increased drastically in the last 10 years. The average price of ethanol was $1.47 per gallon between 1997 and 2006. The price rose from $1.01 in 1999 to $2.56 in 2006.

The large jump can be attributed to the 1996 phase out of lead in vehicles, increased gasoline and corn prices, and the renewable fuel standard for biofuels.

Agriculture operates in a special environment that often subjects farmers to a great deal of risk. Not accounting for risk potentially leads to incomplete information for stakeholders. Feasibility studies for agribusinesses such as ethanol plants must incorporate risk in the analysis due to the riskiness of the prices of feedstocks—corn, sweet sorghum, or sugarcane and the risk associated with ethanol prices.

Point vs. Probabilistic Simulation

Risk can be modeled several ways depending on the view of the researcher. Sensitivity analysis and probabilistic simulation in economics have been employed to account for risk in economic systems. Both methods deal with “what-if” situations, yet they are different in the approach taken to arrive at information used to make decisions.

Sensitivity analysis is often used to determine the key variables that are critical in a model (Richardson 2007). Business decision models often find sensitivity analysis useful in identifying variables that have large or small affects on the key output variable, such as profit.

The results provided by point estimates, or single values, may be skewed or provide an incomplete picture of the situation, hiding the riskiness of a decision (Hardaker et al. 2004a, p. 8; Pouliquen 1970, p. 8; Reutlinger 1970). Best and worst case scenarios as well as average outcome fail to disclose the probability of those and all other outcomes. These techniques have a high probability of providing inaccurate and incomplete results.

In contrast to sensitivity analysis, probabilistic simulation uses a probability distribution for each stochastic variable. Historical data for stochastic variables are analyzed to estimate parameters for simulating their associated distributions (Pouliquen 1970, p. 3; Reutlinger 1970). The accuracy of the model results is dependent on the reliability of the probability distributions.

Reutlinger (1970) asserts that risk is subjective therefore the preferred option must be left to the decision maker, not the researcher. Probabilistic simulation develops a probability distribution for possible outcomes of stochastic variables. Using the probability distribution of key output variables for different business decisions allows the stakeholder to choose the scenario that best fits his or her risk aversion level (Hardaker et al. 2004b, p. 253).

Monte Carlo Simulation

Monte Carlo simulation is a popular methodology for analyzing business decisions under risk. Credit for the creation of this method is often given to Ulam in 1946 but can also be attributed to Fermi in Rome during the thirties (Metropolis 1987). Ulam initially devised this technique to be used as a "statistical approach to solving the problem of neutron diffusion in fissionable material" (p. 127), while trying to build the atomic bomb. Some decades later, experimental math was formed using Monte Carlo simulation.

Monte Carlo simulation is based on uniformly distributed pseudo-random numbers. The uniform numbers are then transformed to non-uniform distributions that can be used to simulate complex and multi-dimensional problems (Metropolis 1987). A higher number of iterations specified in the model yields more accurate probability distributions for the key output variables (Vose 2000, p. 41).

Monte Carlo simulation has been used extensively in economic analyses (Bise 2007; Fumasi 2005; Ray et al. 1998) and ethanol and bio-fuel feasibility studies (Outlaw et al. 2007; Ribera et al. 2007a; Ribera et al. 2007b; Richardson et al. 2007a; Richardson, Lemmer, and Outlaw 2007b; Lau 2004; Herbst 2003; Gill 2002) to account for risk in business decisions. Advances in risk modeling have increased the accuracy of the forecasts to make Monte Carlo simulation more popular. All of the above authors, with the exception of Ray et al. (1998), used Latin hypercube sampling. The modification to the Monte Carlo method by using Latin hypercube sampling requires fewer samples to get an accurate estimate of the empirical probability density function (PDF) for the key output variables (KOVs) (Hardaker et al. 2004a, p. 166). Latin hypercube sampling ensures that samples are pulled from each interval (1/number of iterations) in the uniform distribution. The Monte Carlo method may pull samples from a concentrated area under the uniform distribution creating bias in the sampling processes and results. Bias will prevent the model from reproducing the parent distribution and can only be detected by applying statistical validation tests (Richardson 2007). Using Latin hypercube sampling reduces this bias and gives an output that is much more accurate than using Monte Carlo sampling (Hardaker et al. 2004a, p. 167).

Richardson et al. (2007a) demonstrated the benefit of using Monte Carlo probabilistic simulation with Latin hypercube sampling over deterministic estimation. The study modeled a 50 million gallon ethanol plant in Texas over 10 years. Stochastic variables were simulated from historical data using the multivariate empirical (MVE) distribution to account for correlation among the variables. Pro forma financial statements were used in the comparison. The stochastic variables were used in the equations to calculate receipts, expenses, cash flows, financial ratios, and key output variables for the probabilistic statements. The stochastic variables were held at their mean values for the deterministic analysis.

The Richardson et al. (2007a) deterministic model concluded that the average cost of production (COP) was $1.46 per gallon of ethanol, with an average annual net return (ANR) of $3.67 million, average annual ending cash reserves (AECR) of $22.15 million, a net present value (NPV) of -$26.80 million, a rate of return on investment (ROI) of 6.06%, and present value of ending net worth (PVENW) of $38.26 million (Richardson et al. 2007a). The probability of economic success could not be determined.

The stochastic model supplied more robust information (Richardson et al. 2007a). The average COP of $1.47 per gallon for ethanol was comparable to the deterministic figure, but the remaining results from the stochastic analysis were less optimistic in regards to profitability. The ANR was $1.97 million with a standard deviation of $4.37 million. Average AECR was estimated to be $9.96 million with a standard deviation of $20.02 million. The NPV and ROI was -$38.48 million and 4.95% with standard deviations of $30.19 million and 3.64%, respectively. The PVENW of $27.22 million was more than $10 million less than the point estimate and had a standard deviation of $16.92 million. The probability of economic success for the ethanol plant was 9.40%. The probability of PVENW and ROI being less than 0.0 was 6.46 and 9.12%, respectively. The probability of the debt to asset ratio being greater than 0.75 was 13.60%.

Ranking Risky Alternatives

Stakeholders are better able to choose among risky alternatives if they are provided information to rank the scenarios from best to worst. Some very simple ranking methods use the summary statistics, but there are better means for ranking risky alternatives (Richardson 2007). Stochastic efficiency with respect to a function (SERF) utilizes the empirical probability distributions simulated for each risky alternative to determine which alternative is preferred for risk averse decision makers (Richardson 2007). The scenarios are ranked simultaneously from highest to lowest certainty equivalency at each risk aversion level (Hardaker et al. 2004b, pp. 255-56). A power utility function is used to calculate the certainty equivalent (CE) at all risk aversion levels for risk averse decision makers. The result of using SERF is a chart which indicates the rankings of risky alternatives for all risk aversion levels from risk neutral to extremely risk averse based on the CEs. The chart is easy to interpret, yet is based on sophisticated advanced utility maximization procedures and theory.

Summary

High gasoline prices and movement towards more eco-friendly transportation fuels has given rise to interest in ethanol once again. Increased corn production for ethanol has shifted some planted acres to more profitable crops and increased the prices of grain crops. The demand for corn has been blamed for increased consumer food and livestock feed prices. Furthermore, corn has been identified as a feedstock that may have negative impacts on the environment. Other ethanol feedstocks and technology are being analyzed to find a more efficient feedstock that has fewer negative impacts on society in general.

There has been extensive research on ethanol in terms of energy efficiency, economic feasibility, environmental impact, and feedstock use in different geographical locations. The type of feedstock, size of the refinery, the cost of the feedstock, the distance and cost of transportation, and the amount of feedstock available were important determinants of the economic feasibility of ethanol production.

There is a gap in the literature regarding ethanol production from sweet sorghum in the United States. The majority of sweet sorghum research has been conducted in foreign countries and is not necessarily comparable to the United States. Without research over a variety of feedstocks, the most efficient and suitable feedstock may not be identified causing profits and best practices to be forfeited. Research based on sweet sorghum trials or experience in the United States is needed to provide accurate information for stakeholders.

The feasibility of ethanol production from sweet sorghum in Texas has not been considered over a wide range of conditions. Most research has been conducted in the southeast areas of the United States. Texas offers a wide range of conditions that might support successful ethanol production. This research will provide information on ethanol production from sweet sorghum juice in Texas.

All of the feasibility studies in the literature review, with the exception of Outlaw 2007, Ribera 2007a and 2007b, Richardson et al. 2007a and 2007b, and Herbst 2003, ignore risk in their models. The inclusion of risk allows stakeholders to make a decision based on probability distributions for key output variables. Risk is by far one of the hardest factors to account for, but it is naïve of researchers to suggest that a complete and thorough feasibility analysis can be developed from a deterministic model.

CHAPTER III

METHODOLOGY

The probability distributions for farmer and ethanol producer profits will be estimated to assess the economic feasibility of ethanol production from sweet sorghum juice in Texas. Monte Carlo simulation will be applied to financial statements developed for the farm and ethanol biorefinery and will incorporate risk for variables that are not controlled by the decision makers. Monte Carlo simulation has been used in similar economic feasibility studies (Outlaw et al. 2007; Ribera et al. 2007a; Ribera et al. 2007b; Richardson et al. 2007a; Richardson, Lemmer, and Outlaw 2007b; Lau 2004; Herbst 2003; Gill 2002) and is the best method to evaluate risk in a business project (Pouliquen 1970). Monte Carlo simulation is necessary to determine the threshold prices for farmers to grow sweet sorghum for ethanol production and the probability of success for the biorefinery over several years given price and scenario changes.

Simulation

Simulation is a mathematical representation of actual systems that cannot be experimented on directly for the purpose of answering “What if…” questions (Richardson 2007). Simulation is used to determine the effects of exogenous variables and different scenarios on output variables of interest to the decision maker.

Deterministic and stochastic simulation are two common techniques to analyze a “What if…” question (Richardson 2007). Deterministic simulation calculates a possible outcome based on a point estimate such as the mean for exogenous variables. The probability of the point estimate occurring is not taken into consideration so risk is ignored and there is bias in the output (Pouliquen 1970, p. 2).

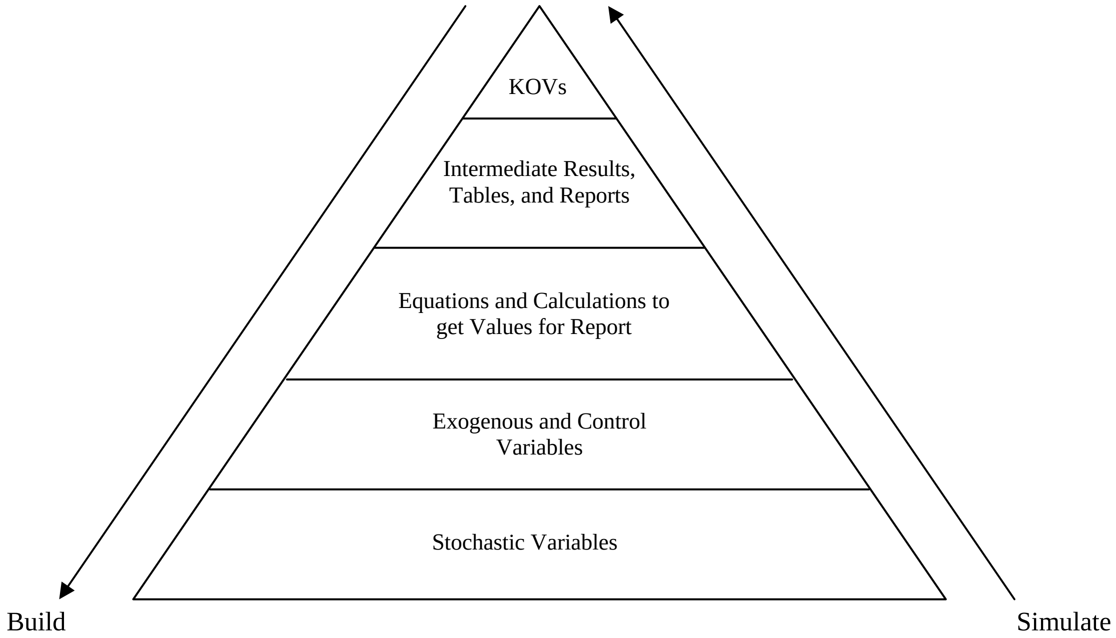
Stochastic simulation uses probability distributions of exogenous variables to calculate a distribution for all possible outcomes (Pouliquen 1970, p. 2). The risk surrounding the variables is accounted for in the model and results in output with assigned probabilities of occurrence. The decision maker is able to determine the best action to take given his aversion to risk by using the output variable probability distribution.

Pouliquen (1970), Reutlinger (1970), and Richardson (2007) affirm that stochastic simulation is the best method to analyze decisions that involve risk. Based on the literature, this thesis will use stochastic simulation to model the feasibility of producing ethanol from sweet sorghum juice in Texas.

Model Components and Development

The steps to develop a stochastic simulation model are outlined in Richardson (2007) and Richardson and Mapp (1976). Variables that affect the outcome of a project need to be identified first, then assigned a probability distribution if stochastic. Deterministic control variables should be established. The next step is to form equations that tie the stochastic and deterministic values together. The accounting relationships should be specified and linked to the stochastic and deterministic equations to incorporate risk into the financial model. Stochastic values for output variables are calculated using the accounting equations, then simulated to form probability distributions of the output to evaluate the project.

Developing a stochastic simulation model is best completed in a top-down approach (Richardson 2007). By determining the key output variables (KOVs), the underlying model components can be identified. Intermediate output variables (such as those in financial statement: income, cash flow, and balance sheet), equations to calculate output variable values, and exogenous, control, and stochastic variables are used to observe the KOVs. Figure 1 illustrates the best way to build and simulate a stochastic model. The model should be designed from the top-down, and programmed from the bottom up for the best results (Richardson 2007).



*Key Output Variables (KOVs)

Figure 1. Steps to Develop and Program a Stochastic Simulation Model

Model Verification and Validation

Verification and validation are key to any model and occur throughout the development and simulation stages. Verification is the process of testing every equation in the model to insure that it calculates correctly as well as checking the logic of the model to insure all equations are properly specified (Richardson 2007). Verifying the use and accuracy of the equations confirms the reliability of the model. Verification is part of validating the model.

Validation is the process of testing the accuracy of random variables and forecasts generated by the model (Richardson 2007). The random variable distributions should be checked before linking them to the deterministic variables to make sure they have the same characteristics as the parent distributions. The student t-test and the correlation matrix test are used for model validation. Using a cumulative distribution function (CDF) to visually validate the random variable probability distributions is also acceptable.

The data used in the farm and ethanol model require validation and verification. Stochastic prices were provided by the Food and Agricultural Policy Research Institute (FAPRI 2008). The mean, standard deviation, minimum, maximum, and correlation matrix for yields and prices used in the model will be verified to insure that all yields and prices are simulated properly. The equations used in the enterprise budgets, income statement, cash flow, and balance sheet will be verified for accuracy.

Simulating a model without verifying and validating the numerous equations and variables included in the model increases the potential for costly output errors. Reliable information is necessary to help stakeholders make the best decision.

Decision makers are often faced with more than one project scenario, each involving different risk. Stochastic simulation is capable of analyzing and ranking numerous scenarios from what is perceived to be the best to the worst. Regardless of the rankings provided by the analysis, only the stakeholder can choose the best option for his situation.

There are numerous ranking methods, but the preferred ranking method is stochastic efficiency with respect to a function (SERF) (Hardaker et al. 2004b). The SERF analysis simultaneously evaluates certainty equivalencies (CEs) across a range of risk aversion coefficients (RACs) for several scenarios (Richardson 2008). The CEs for each scenario are calculated over 25 RACs uniformly distributed between an upper and lower RAC. The scenario with the highest CE is preferred at any given RAC, thus rankings can change over different risk aversion levels. The CE results are reported in a table and can be presented in a chart. The SERF procedure requires assuming a utility function.

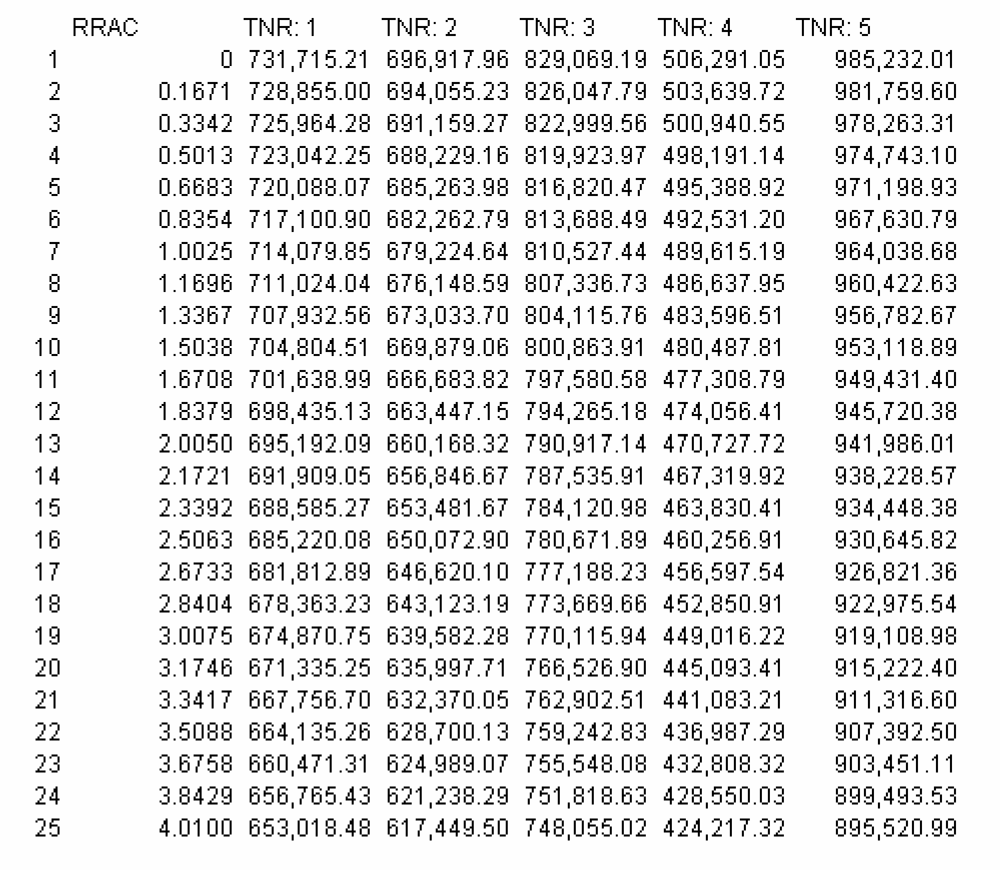
The Power Utility function is best suited for ranking risky alternatives that span a multiple year time horizon (Richardson 2008). Anderson and Dillon (1992) refer to the Power Utility function as the additive separable assumption for the same utility function used for each consumption outcome over a multi-period context. The Power Utility function remains fixed over multiple scenarios to calculate utility based on the same utility criteria (Anderson and Dillon 1992, p. 62).

The parameters required for the Power Utility function are the relative risk aversion coefficients (RRACs) and a specified wealth amount. A decision maker is assumed to have a constant relative risk aversion as wealth increases when using the Power Utility function. Constant relative risk aversion allows SERF to rank scenarios over different wealth levels because it assumes that a stakeholder has the same risk aversion when his wealth changes relative to the dollar amount at stake. Table 1 and Figure 2 are examples of SERF output assuming a Power Utility function over a RRAC of 0 to 4 for ranking five risky scenarios. The lower and upper RRAC of zero and four represent risk neutral and extremely risk averse individuals, respectively. The initial wealth required for the Power Utility function can be determined from the financial statements and is unique for each model. The CEs for each scenario are calculated at 25 RRAC intervals shown under the RRAC heading in Table 1.

The scenario with the greatest CE, reading across the row, is most preferred at each specific RRAC. For instance, scenario five is preferred by a rational decision maker regardless of his aversion to risk because it has the greatest CE at all RRACs Table 1. If two scenarios have equal CEs at a RRAC, then any decision maker who has the particular RRAC would be indifferent between them.

The SERF chart in Figure 2 is interpreted similar to the SERF table. Scenario five is preferred over the other scenarios because it has the highest CE at each RRAC. Scenario four is least preferred among the options as it has the lowest CE at each RRAC.

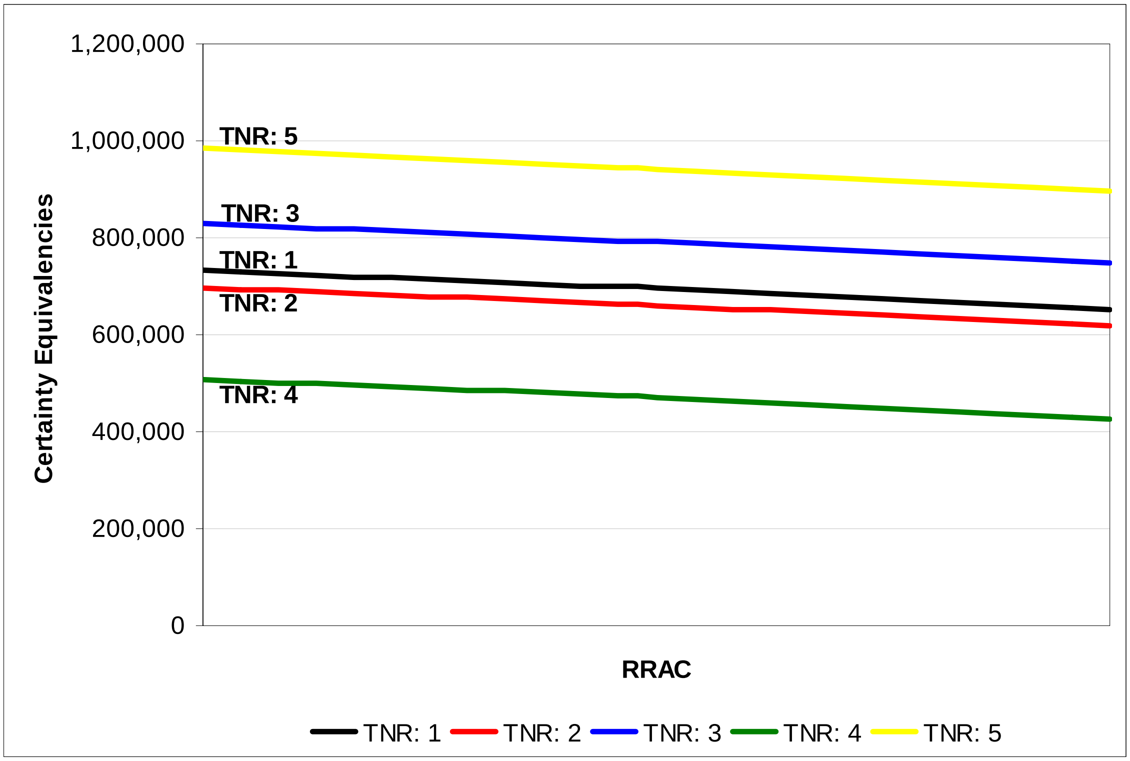
Table 1. SERF Table Assuming a Power Utility Function to Rank Five Risky Scenarios



	RRAC	TNR: 1	TNR: 2	TNR: 3	TNR: 4	TNR: 5
1	0	731,715.21	696,917.96	829,069.19	506,291.05	985,232.01
2	0.1671	728,855.00	694,055.23	826,047.79	503,639.72	981,759.60
3	0.3342	725,964.28	691,159.27	822,999.56	500,940.55	978,263.31
4	0.5013	723,042.25	688,229.16	819,923.97	498,191.14	974,743.10
5	0.6683	720,088.07	685,263.98	816,820.47	495,388.92	971,198.93
6	0.8354	717,100.90	682,262.79	813,688.49	492,531.20	967,630.79
7	1.0025	714,079.85	679,224.64	810,527.44	489,615.19	964,038.68
8	1.1696	711,024.04	676,148.59	807,336.73	486,637.95	960,422.63
9	1.3367	707,932.56	673,033.70	804,115.76	483,596.51	956,782.67
10	1.5038	704,804.51	669,879.06	800,863.91	480,487.81	953,118.89
11	1.6708	701,638.99	666,683.82	797,580.58	477,308.79	949,431.40
12	1.8379	698,435.13	663,447.15	794,265.18	474,056.41	945,720.38
13	2.0050	695,192.09	660,168.32	790,917.14	470,727.72	941,986.01
14	2.1721	691,909.05	656,846.67	787,535.91	467,319.92	938,228.57
15	2.3392	688,585.27	653,481.67	784,120.98	463,830.41	934,448.38
16	2.5063	685,220.08	650,072.90	780,671.89	460,256.91	930,645.82
17	2.6733	681,812.89	646,620.10	777,188.23	456,597.54	926,821.36
18	2.8404	678,363.23	643,123.19	773,669.66	452,850.91	922,975.54
19	3.0075	674,870.75	639,582.28	770,115.94	449,016.22	919,108.98
20	3.1746	671,335.25	635,997.71	766,526.90	445,093.41	915,222.40
21	3.3417	667,756.70	632,370.05	762,902.51	441,083.21	911,316.60
22	3.5088	664,135.26	628,700.13	759,242.83	436,987.29	907,392.50
23	3.6758	660,471.31	624,989.07	755,548.08	432,808.32	903,451.11
24	3.8429	656,765.43	621,238.29	751,818.63	428,550.03	899,493.53
25	4.0100	653,018.48	617,449.50	748,055.02	424,217.32	895,520.99

Note: Stochastic Efficiency with Respect to a Function (SERF), Relative Risk Aversion Coefficient (RRAC),Total Net Returns (TNR)

A decision maker is indifferent between two scenarios if the CE lines representing the scenarios intersect at the decision maker's RRAC. The SERF chart mirrors the SERF table exactly and can be used as a visual aide for decision makers when ranking risky alternatives. If the CE lines never cross, we conclude that all decision makers who have RRACs over the range prefer the same risky alternatives, the highest CE line being the most preferred over all alternatives.



Note: Stochastic Efficiency with Respect to a Function (SERF), Relative Risk Aversion Coefficient (RRAC), Total Net Returns (TNR)

Figure 2. SERF Chart Assuming a Power Utility Function for Ranking Five Risky Scenarios

Monte Carlo simulation using stochastic variables to produce key output variables is advantageous when several different risky scenarios are being considered by a decision maker. Ranking risky scenarios is an important step in identifing the preferred decision based on the decision maker's aversion to risk. Stochastic simulation and ranking will be used in the farm model to select the price that a farmer would accept to grow sweet sorghum. Net present value will be simulated and ranked in the ethanol model.

CHAPTER IV

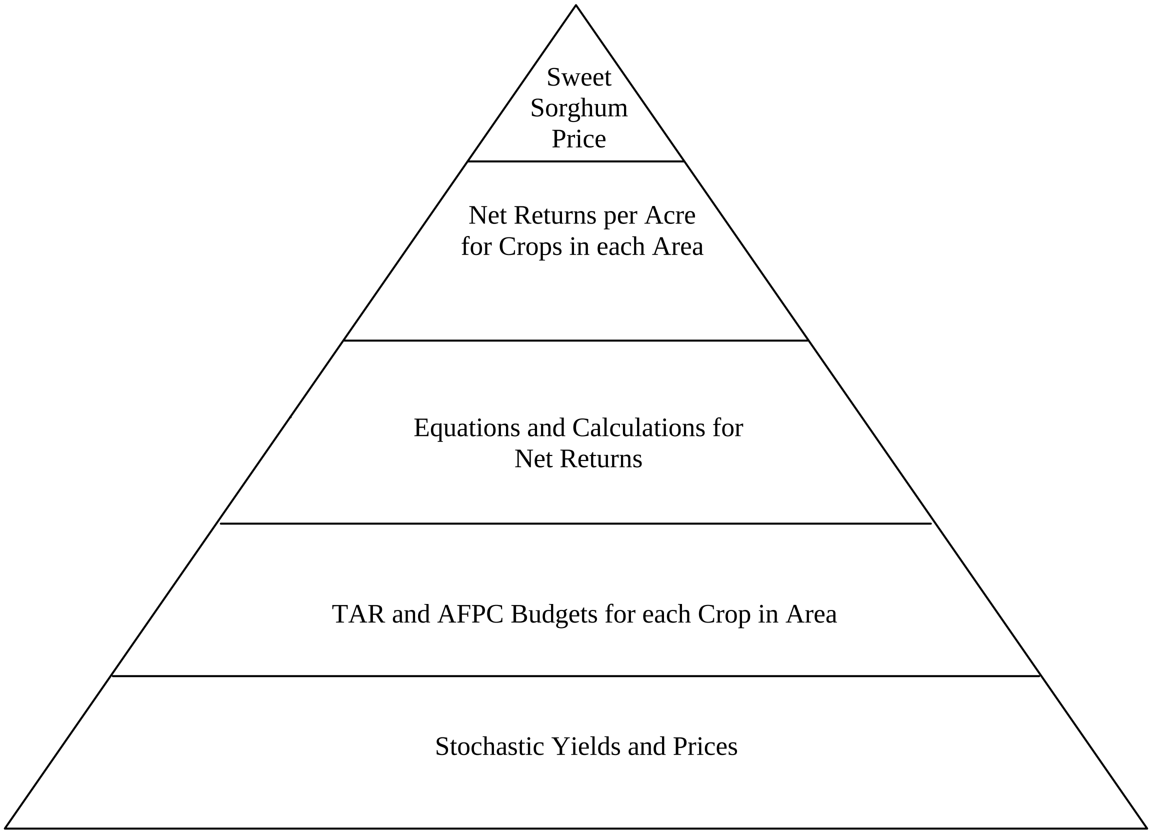
DESCRIPTION OF THE MODEL

Two separate models will be built for each study area: one for a sweet sorghum farmer (farm) and another for an ethanol producer. The farm model will be used to calculate the minimum sweet sorghum price that could be offered to sweet sorghum producers by an ethanol plant in each area to guarantee sweet sorghum production. The ethanol model will calculate annual ending cash (EC) and net present value (NPV) using the sweet sorghum price and other factors to estimate the probability of success for an ethanol plant. This chapter describes the development of both models.

Sweet Sorghum Producer (Farm) Model

Several assumptions will be made regarding farming practices and the price offered to sweet sorghum farmers. The first assumption is that farmers currently produce the most profitable crop mix given their resources; therefore, the price paid to grow sweet sorghum must be greater than the net returns from the current crop mix. The second assumption is that farmers would be willing to grow sweet sorghum if paid a contract price larger than their opportunity price for current crops and/or the cost of sweet sorghum production plus a 10% profit. Finally, farmers are assumed to be rational and risk averse decision makers.

The pyramid in Figure 3 depicts the stages for building the farm model from the top down. The key output variable (KOV) in the farm model will be the price offered to farmers to produce sweet sorghum in each area. Budgets provide itemized production expenses for costs in each study area. Revenues and expenses to calculate net returns for the competing crops and total costs for sweet sorghum will be calculated using stochastic prices and yields and current budgets for the crops.



Note: Texas AgriLife Research (TAR), Agricultural and Food Policy Center (AFPC)

Figure 3. Stochastic Farm Model for Each Study Area

Farm Model Variables

This section describes the farm model structure starting with the stochastic and deterministic variables (Figure 3). The market price and yield for crops change each growing season; therefore it is logical to make these variables stochastic. Stochastic prices and yields for the competing crops listed in Table 2 will be simulated for the ten year planning horizon for each study area. Stochastic market prices and yields for irrigated cotton and grain sorghum in Willacy County, rice in Wharton County, irrigated corn, grain sorghum, and wheat in Moore County, and dryland corn, grain sorghum, and wheat in Hill County will constitute the stochastic variables for the competing crops in the farm model. A multi-variate empirical (MVE) probability distribution will be used to simulate the crop yields. The product of the annual stochastic market price and yield will represent stochastic revenue. The annual stochastic yield for sweet sorghum will also be simulated for each county and is included in the yield MVE distribution.

Table 2. Competing Crops in Each County

County:	Competing Crops:
Willacy	Irrigated Cotton
	Irrigated Grain Sorghum
Wharton	Rice
Moore	Irrigated Corn
	Irrigated Grain Sorghum
	Irrigated Wheat
Hill	Dryland Corn
	Dryland Grain Sorghum
	Dryland Wheat

Annual crop prices for competing crops are simulated for 2008 by the Food and Agricultural Policy Research Institute (FAPRI 2008). The FAPRI baseline prices will be increased by a fraction to make the 2008 projected price equal to the 2008 observed price on the Chicago Mercantile Exchange. To localize FAPRI's stochastic national prices, price wedges will be calculated between Texas crop prices and national prices. The 2008 stochastic Texas price forecasts will be used in the farm model.

Data to estimate parameters for the MVE yield distribution will come from a CroPMan simulation of 47 years using actual weather data for each study area. Average CroPMan yields will be validated against the county yields in each area. Sweet sorghum yields to estimate parameters for the MVE distribution will come from Texas AgriLife Research (TAR) field trial yields conducted by Rooney and Blumenthal (2007). The MVE distribution for crop yields will be used to ensure past correlation between crops is reflected in the simulated values, and the coefficient of variation (CV) for the simulated variables will equal the CV of the historical data. The simulated crop yields will be scaled to their respective average yields reported by farmers to the Agricultural and Food Policy Center (Herbst et al. 2007.) farm budgets. Sweet sorghum yields simulated by the MVE distribution will be scaled to average yields based on yield test trials. Adjusting the stochastic yield values will be necessary to insure that the net returns per acre will be representative of the farms in each study area. Opportunity costs for growing sweet sorghum will be calculated using enterprise budgets to determine the minimum price to pay for sweet sorghum.

Enterprise Farm Budgets

Enterprise budgets will be used to estimate the total costs for the crops in each area. Variable and fixed costs per acre will be available from the AFPC and Texas AgriLife Extension Service (TALES) budgets. Total costs per acre and stochastic receipts will be used to calculate the net returns of the competing crops. Table 3 outlines the input and output variables for the farm model. The crop enterprise budgets will be discussed in the next chapter. Budgets for producing sweet sorghum will be developed based on results from TAR field trials and budgets for sweet sorghum combined with expert advice from Dr. Rooney.

Table 3. Input and Output Variables for the Farm Model

Input Costs for All Crops:	Yields for:
Price of the Crop	**Sweet Sorghum**
Storage	**Competing Crops**
Irrigation	
Seed	
Labor	
Repairs	
Fertilizer	
Planting and Soil Preparation	
Equipment	
Fixed Costs	

Note: Bold names indicate the variables will be stochastic.

Calculating the Sweet Sorghum Price

One purpose of the farm model will be to calculate a price for sweet sorghum. The minimum price for sweet sorghum will depend on the expected production cost of sweet sorghum and the expected profit from the next best alternative crop in the region.

The MVE distribution for crop yields will be used to simulate stochastic yields. Correlated uniform standard deviates (CUSDs) will be simulated using a correlation matrix of CroPMan yields. Empirical distributions for each crop's yield will be expressed as percentage deviates (S_i) from the mean (as the historical data has no trend) and probabilities of occurrence ($F(S_i)$). The CUSDs (C_i), deviates (S_i), and probabilities ($F(S_i)$) will be used with the forecasted mean yields ($\hat{Q}_j$) to simulate random crop yields ($\tilde{Q}_j$) in each study area for each crop (1).

(1) $\tilde{Q}_j = \hat{Q}_j * [1 + MVE(S_i, F(S_i), C_i)]$

The stochastic yields will be used with the enterprise budgets to calculate revenues and costs. Total stochastic revenue for each competing crop ($\tilde{T}R_j$) will be a function of the stochastic price ($\tilde{P}_j$) and yield per acre ($\tilde{Q}_j$) (2).

(2) $\tilde{T}R_j = \tilde{P}_j * \tilde{Q}_j$

Total cost for each competing crop (TC_j) and sweet sorghum will be the sum of the variable (VC_{ji}) and fixed costs per acre (FC_j) (3).

(3) $TC_j = \Sigma(VC_{ji}) + FC_j$

Stochastic profit for each crop ($\tilde{\prod}_j$) will equal the total stochastic revenue ($\tilde{T}R_j$) minus the total cost (TC_j) (4).

(4) $\tilde{\Pi}_j = T\tilde{R}_j - TC_j$

The minimum price for sweet sorghum will be the maximum of either the expected production cost of sweet sorghum plus 10% (TC_{ss}) or the expected profit from the next best alternative crop in the region ($\tilde{\Pi}_j$) (5).

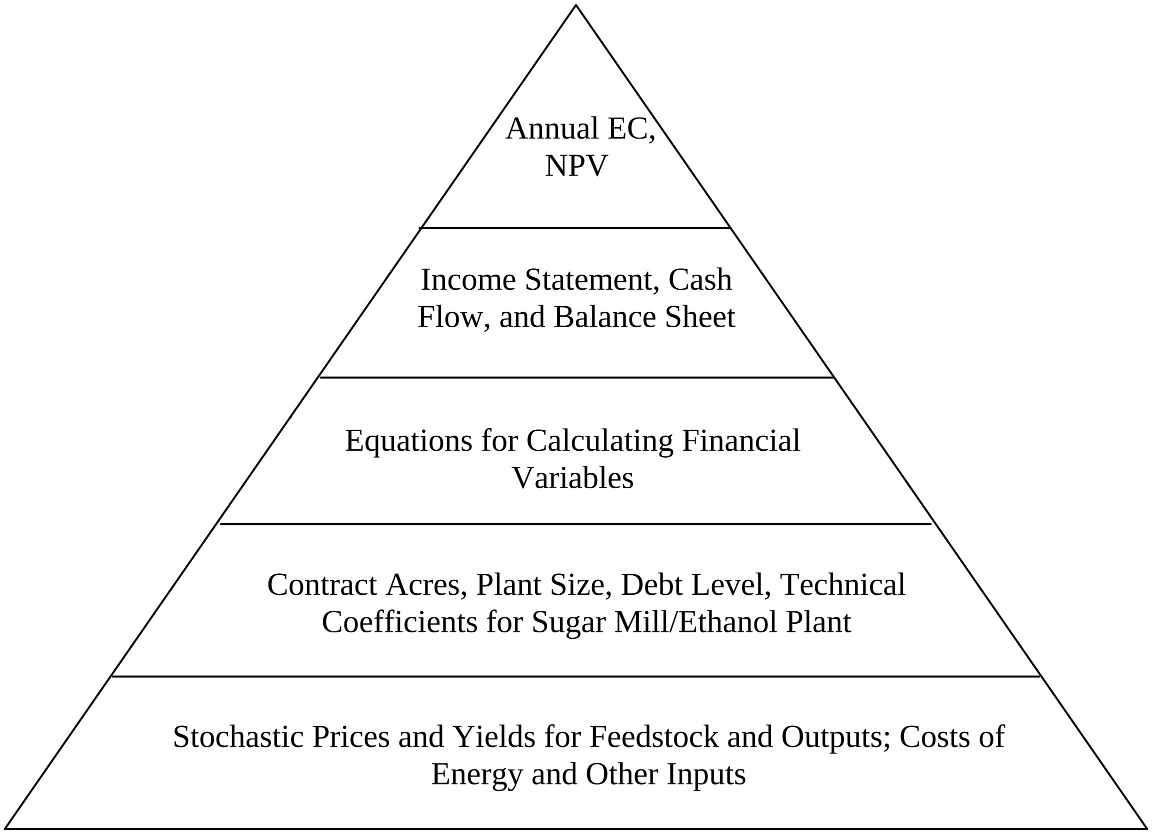
(5) $\tilde{P}_{ss} = \text{Max}[(TC_{ss}*1.1), \tilde{\Pi}_1, \tilde{\Pi}_2, \tilde{\Pi}_3 ...]$

The same model structure will be used to develop a farm model for each study area.

Ethanol Producer (Ethanol) Model

The pyramid in Figure 4 depicts the steps for building the ethanol model from the top down. The ethanol plant model will be built to simulate the probability of economic success for the ethanol plant under alternative production scenarios. Annual ending cash (EC) and net present value (NPV) will be the KOVs used as determinants of economic success for the ethanol plant. Standard accounting formulas from the income statement, cash flow, and balance sheet will be the essence of the ethanol plant model as these statements contain the variables to calculate the KOVs. Control settings for plant size and technical coefficients for the ethanol plant will differ for each study area. The contract price for sweet sorghum, contract acres, stochastic sweet sorghum yields, stochastic prices for additional feedstocks (corn), and stochastic costs of energy and other inputs will be used in the model to simulate probability distributions for the KOVs.

The ethanol plant will use sweet sorghum for the duration of the harvest period in each study area. Willacy County will be able to harvest sweet sorghum from June through mid-December. Operation using sweet sorghum will be shorter in Wharton



Note: Ending Cash (EC), Net Present Value (NPV)

Figure 4. Stochastic Ethanol Plant Model for Each Study Area

County where harvests will take place between July and mid-November. An ethanol plant in Hill County will be able to use sweet sorghum between late July and November, while Moore County will be able to operate between September and mid-October in some years. Corn will be used to make ethanol when sweet sorghum is not available.

Contracted acres are a function of the average yield per acre and the average number of days sweet sorghum is used to produce ethanol. Each study area will contract enough acres each year to produce ethanol at 75% capacity. By contracting fewer acres than the ethanol plant can process, it hedges against the risk of low yields or fewer sweet sorghum operating days and capitalizes on seasons where excess production is possible.

Stochastic corn prices available from FAPRI (2008-2017) will be used to simulate prices for the corn feedstock. The FAPRI corn price will be inflated to reflect the observed increase seen in 2008. Historical energy prices available from the Energy Information Administration (EIA) will be combined with an AFPC forecast of ethanol prices to simulate ethanol prices for the model.

The quantity of sweet sorghum feedstock available will be simulated from the crop yields used in the farm model and the acres contracted. French's formula for estimating the area needed to supply (grow) a given quantity of a feedstock will be used to calculate hauling costs for sweet sorghum (French 1960).

Construction cost estimates for the ethanol plant will be developed using costs obtained from Dedini of Brazil (2007). Ethanol, electricity, bagasse, and vinasse (residual liquid from sugar ethanol) production will be calculated based on input and output coefficients for Brazilian sugarcane alcohol plants. Bagasse is the sweet sorghum dry matter that remains intact after squeezing the stalks and vinasse is the residual liquid from sugar ethanol and is used as a feed supplement. Inflation and interest rate projections from FAPRI will be used for the 10 year planning horizon.

Ethanol Plant Model Variables

The following pages explain the ethanol plant model (Figure 4) in greater detail, starting with the stochastic and deterministic variables and ending with the key output variables. Stochastic variables for the ethanol plant model will be the prices for corn, electricity, gasoline, natural gas, and ethanol as well as the quantity of feedstock available and, thus, the quantity of ethanol, electricity, bagasse, vinasse, and WDGs produced. Table 4 shows the input and output variables for the ethanol model.

The sweet sorghum contract price will be calculated in the farm model. The corn, ethanol, electricity, gasoline, and natural gas prices will be simulated using an MVE distribution. The price of vinasse will be simulated using a GRKS distribution as no historical series is available for estimating parameters for its distribution.

Table 4. Input and Output Variables for the Ethanol Model

Inputs:	Outputs:	Input and Output Prices:
Sweet Sorghum	**Ethanol**	Sweet Sorghum
Corn	**Electricity**	**Corn**
	Vinasse	**Ethanol**
Plant Construction:	**Bagasse**	**Electricity**
Land	**WDGS**	**Gasoline**
Mill/processing		**Natural Gas**
Fermentation/distillation		**Vinasse**
Boiler/generator		**WDGS**
		Labor
Operation:		Management
Electricity		Chemicals
Gasoline		Maintenance
Natural Gas		Water
Labor		
Management		
Chemicals		
Maintenance		
Water		

Note: Wet Distillers Grains with Solubles (WDGS); Bold names indicate the variables that are stochastic.

Deterministic variables such as utilities, labor, management, and other operation inputs will be used in the income statement to calculate the expenses for the ethanol plant (Table 4). Plant construction costs will be deterministic due to the fixed cost of the construction. Inflation and interest rate projections will be applied to the operating costs to account for changes in the economic market.

Estimating the Probability of Economic Success

Ethanol plant profits will depend on the days in operation, costs of production, and price and quantity of outputs. This section outlines the equations used to calculate the probability of economic success beginning with the operation time, receipts, and costs, and concluding with the key output variables.

Operation Time

The days the plant can operate using sweet sorghum as the sole feedstock will be dependent on the number of days required to grow a crop and the number of frost free days in each study area. The daily weather reports for the past 47 years in each study area will be used to simulate the number of days without a frost and the number of days the plant can operate using sweet sorghum. Truncated Normal distributions will be used to simulate the stochastic number of days without a freeze each year ($\tilde{FF}_t$) for each region. The average, standard deviation, minimum, and maximum number of days without a freeze will be used as parameters for the distribution (6).

(6) $\tilde{FF}_t$=TNORM(average,standard deviation,minimum,maximum)

Estimated days for the first and subsequent cuttings of sweet sorghum to grow and mature will be indicators of the number of harvests possible each year, by study area. The probability of harvesting one, two, or three times ($\tilde{P}rob_{n\ cut;t}$) will be contingent on the number of frost free days in the year ($\tilde{F}F_t$) and the total number of days required for sweet sorghum to reach maturity (G_n) in each study area. If the number of frost free days is greater (less) than the number of days sweet sorghum requires to grow and mature, then the first harvest is possible and will be denoted as a one (zero) (7 and 8). If the number of frost free days is greater (less) than the number of days to grow the crop for two harvests, the second harvest will be denoted as a one (zero) (9 and 10), and so on (11 and 12).

(7) $\tilde{P}rob_{1st\ cut;t}=IF(\tilde{F}F_t>G_{1st})=1$

(8) $\tilde{P}rob_{1st\ cut;t}=IF(\tilde{F}F_t<G_{1st})=0$

(9) $\tilde{P}rob_{2nd\ cut;t}=IF(\tilde{F}F_t>G_{1st}+G_{2nd})=1$

(10) $\tilde{P}rob_{2nd\ cut;t}=IF(\tilde{F}F_t<G_{1st}+G_{2nd})=0$

(11) $\tilde{P}rob_{3rd\ cut;t}=IF(\tilde{F}F_t>G_{1st}+G_{2nd}+G_{3rd})=1$

(12) $\tilde{P}rob_{3rd\ cut;t}=IF(\tilde{F}F_t<G_{1st}+G_{2nd}+G_{3rd})=0$

The ethanol plant's operating time using sweet sorghum ($\tilde{O}p_{ss}$) will be the number of frost free days ($\tilde{F}F_t$) minus the number of days required to grow each crop to be harvested (G_n) (13).

(13) $\tilde{O}p_{ss}=\tilde{F}F_t-G_n$

The difference between the number of days in a year, the stochastic operation using sweet sorghum ($\tilde{O}p_{ss}$), and down time (DT) to clean the plant, will be the number of days the plant uses corn ($\tilde{O}p_{corn}$) to produce ethanol (14).

(14) $\tilde{O}p_{corn}=365-\tilde{O}p_{ss}-DT$

Revenue

Prices and quantities for ethanol, green electricity, vinasse, and wet distillers grain (WDGS) will be used to calculate the revenues earned by the refinery. Ethanol prices for 2008-2017 will be simulated using an MVE distribution. Ethanol prices are correlated to gasoline, natural gas, and electricity prices using correlated univariate deviates (C_i) obtained from the factored correlation matrix for these variables (15).

(15) $\tilde{P}_{eth}=\hat{P}_{eth}*[1+MVE(S_i,F(S_i),C_{eth})]$

Historical data on green electricity are not available, so an assumed price wedge for green electricity (W_{gelec}) will be used in conjunction with stochastic electricity prices ($\tilde{P}_{elec}$) to simulate the green electricity selling price ($\tilde{P}_{gelec}$). Stochastic electricity prices will be simulated using the MVE distribution (16).

(16) $\tilde{P}_{elec}=\hat{P}_{elec}*[1+MVE(S_i,F(S_i),C_{elec})]$

The fixed wedge (W_{gelec}) will be added to electricity prices to simulate the price of green electricity (17).

(17) $\tilde{P}_{gelec}=\tilde{P}_{elec}+W_{gelec}$

The vinasse price ($\tilde{P}_{vinasse}$) will be simulated with a GRKS distribution using the minimum, middle, and maximum values as parameters (18). The GRKS distribution is described by Richardson, Lemmer, and Outlaw (2007).

(18) $\tilde{P}_{vinasse}=GRKS(minimum,middle,maximum)$

Wet distillers grain prices will be a function of the dried distillers grain (DDGS), price. The local premium for WDGS (W_{WDGS}) will be calculated as the difference between the 2007 DDGS national price ($P_{DDGS;2007}$) and the 2007 Portales, New Mexico WDGS price (19).

(19) $W_{WDGS}=P_{WDGS}-P_{DDGS;2007}$

Historical DDGS prices will be regressed on soybean meal and corn prices and the residuals will be used to simulate stochastic DDGS prices for 2008 through 2017. The stochastic DDGS price coupled with the wedge and an Empirical distribution of the residuals will simulate the price of WDGS ($\tilde{P}_{WDGS}$) (20).

(20) $\tilde{P}_{WDGS}=[\hat{a}+\hat{b}_1\tilde{P}_{SBM}+\hat{b}_2\tilde{P}_{corn}+EMP(residuals)]+W_{WDGS}$

The annual sweet sorghum yield per acre ($\tilde{Q}_{ss}$) and the number of contracted acres (A) in each study area multiplied by the assumed percentage loss (L) will estimate the total quantity of sweet sorghum ($\tilde{T}Q_{ss}$) used to produce ethanol each year (21).

(21) $\tilde{T}Q_{ss}=\tilde{Q}_{ss}*A*L$

The quantity of corn used to produce ethanol ($\tilde{T}Q_{corn}$) will be a function of the days the ethanol plant operates using corn ($\tilde{O}p_{corn}$), the gallons of alcohol produced each day ($\tilde{Q}_{alc/day}$), and the alcohol to corn coefficient (CF_{corn}) (22).

(22) $\tilde{T}Q_{corn}=(\tilde{O}p_{corn}*\tilde{Q}_{alc/day})/CF_{corn}$

The quantity of alcohol produced from sweet sorghum will be modeled based on the crushing, fermentation, and distillation coefficients for sugarcane in Brazil (Fernandes 2003). The efficiency of the squeeze press (SE) and the percent of juice in the stalks (J) will determine the tons of juice extracted ($\tilde{T}Q_{juice}$) from the annual quantity of sweet sorghum squeezed ($\tilde{T}Q_{ss}$) (23).

(23) $\tilde{T}Q_{juice}=\tilde{T}Q_{ss}*J*SE$

The recovered juice ($\tilde{T}Q_{juice}$) will be multiplied by the pounds per ton ($CF_{lbs/ton}$) conversion factors and the brix concentration ($\tilde{B}$) to calculate the kilograms of recoverable sugar per ton of sweet sorghum ($\tilde{T}Q_{sugar}$) (24).

(24) $\tilde{T}Q_{sugar}=\tilde{T}Q_{juice}*CF_{lbs/ton}*\tilde{B}$

The quantity of sugar ($\tilde{T}Q_{sugar}$) multiplied by the juice to alcohol fraction (CF_{juice}) and kilograms per pound ($CF_{kgs/lb}$) conversion factors and divided by the liters per gallon ($CF_{L/gal}$) conversion factor will simulate the total gallons of sweet sorghum alcohol produced annually ($\tilde{T}Q_{ssalc}$) (25).

(25) $\tilde{T}Q_{ssalc}=(\tilde{T}Q_{sugar}*CF_{juice}*CF_{kgs/lb})/CF_{L/gal}$

The total quantity of sweet sorghum ethanol ($\tilde{T}Q_{sseth}$) produced will be simulated as the product of the sweet sorghum alcohol ($\tilde{T}Q_{ssalc}$) and the alcohol to ethanol conversion factor (CF_{alc}) based on the denaturant fraction in the final product (26).

(26) $\tilde{T}Q_{sseth}=\tilde{T}Q_{ssalc}*CF_{alc}$

The quantity of corn ethanol produced ($\tilde{T}Q_{corneth}$) will be the product of the quantity of corn processed ($\tilde{T}Q_{corn}$) and the corn bushels to alcohol gallons factor (CF_{corn}) and alcohol to ethanol conversion factor (CF_{alc}) (27).

(27) $\tilde{T}Q_{corneth}=\tilde{T}Q_{corn}*CF_{corn}*CF_{alc}$

The total quantity of ethanol produced ($\tilde{T}Q_{eth}$) will be the sum of the total quantity of sweet sorghum ($\tilde{T}Q_{sseth}$) and corn ethanol refined ($\tilde{T}Q_{corneth}$) (28).

(28) $\tilde{T}Q_{eth}=\tilde{T}Q_{sseth}+\tilde{T}Q_{corneth}$

Electricity will be generated by burning sweet sorghum bagasse. The quantity of bagasse burned ($\tilde{T}Q_{bagasse}$) will be the product of the quantity of sweet sorghum processed ($\tilde{T}Q_{ss}$) and the percent dry matter (DM) per wet ton of sweet sorghum (29).

(29) $\tilde{T}Q_{bagasse}=\tilde{T}Q_{ss}*DM$

The quantity of green electricity ($\tilde{T}Q_{gelec}$) produced will be determined by the quantity of bagasse burned ($\tilde{T}Q_{bagasse}$) and the kilowatt hours generated per ton of burned matter (CF_{gelec}) (30). Electricity from processing sweet sorghum will be sold as green electricity or used in the ethanol plant. The bagasse-generated electricity will not be available to process corn because electricity is not produced while making ethanol from corn.

(30) $\tilde{T}Q_{gelec}=\tilde{T}Q_{bagasse}*CF_{gelec}$

Vinasse is a byproduct of sweet sorghum ethanol and will be added to the receipts for the ethanol plant. The quantity of vinasse ($\tilde{T}Q_{vinasse}$) produced will be calculated by multiplying the quantity of sweet sorghum alcohol produced ($\tilde{T}Q_{ssalc}$) by the vinasse coefficient ($CF_{vinasse}$) (31). Water will be separated from the vinasse in a centrifuge until the vinasse is reduced to approximately 50% solids.

(31) $\tilde{T}Q_{vinasse}=\tilde{T}Q_{ssalc}*CF_{vinasse}*.5$

Corn alcohol ($\tilde{T}Q_{cornalc}$) multiplied by the coefficient for corn to WDGS (CF_{WDGS}) will simulate the quantity of WDGS produced as a byproduct of corn alcohol ($\tilde{T}Q_{WDGS}$) (32).

(32) $\tilde{T}Q_{WDGS}=\tilde{T}Q_{cornalc}*CF_{WDGS}$

Receipts ($\tilde{R}$) for ethanol, green electricity, vinasse, and WDGS will be simulated as the product of the price ($\tilde{P}$) and quantity ($\tilde{T}Q$) of each output (33-36).

(33) $\tilde{R}_{eth}=\tilde{P}_{eth}*\tilde{T}Q_{eth}$

(34) $\tilde{R}_{gelec}=\tilde{P}_{gelec}*\tilde{T}Q_{gelec}$

(35) $\tilde{R}_{vinasse}=\tilde{P}_{vinasse}*\tilde{T}Q_{vinasse}$

(36) $\tilde{R}_{WDGS}=\tilde{P}_{WDGS}*\tilde{T}Q_{WDGS}$

Subsidies paid to the ethanol refinery could be a source of income. Three subsidies will be programmed into the model. One subsidy will be a dollar amount per ton of sweet sorghum processed, while the other two subsidies will be based on the gallons of sweet sorghum alcohol and corn alcohol produced. Each subsidy ($\tilde{G}S_n$) will be calculated by multiplying the per unit subsidy (GS_n) by the quantity of the good to be subsidized ($\tilde{T}Q_n$) (37-39).

(37) $\tilde{S}_{sstons}=GS_{\$/ton}*\tilde{T}Q_{ss}$

(38) $\tilde{S}_{ssalc}=GS_{\$/galssalc}*\tilde{T}Q_{ssalc}$

(39) $\tilde{S}_{cornalc}=GS_{\$/galcornalc}*\tilde{T}Q_{cornalc}$

The sum of the subsidies received will be the total subsidies paid to the refinery ($\tilde{T}S_n$) (40).

(40) $\tilde{T}S_n=\tilde{S}_{sstons}+\tilde{S}_{ssalc}+\tilde{S}_{cornalc}$

The total receipts ($\tilde{T}R_n$) for the ethanol plant will be the sum of the receipts ($\tilde{R}$) for each output and the subsidies received ($\tilde{T}S_n$) (41).

(41) $\tilde{T}R_n=\tilde{R}_{eth}+\tilde{R}_{gelec}+\tilde{R}_{vinasse}+\tilde{R}_{WDGs}+\tilde{T}S_n$

Total receipts will change each year to indicate the income risk involved in producing ethanol from sweet sorghum and corn.

Expenses

Annual variable input costs to the ethanol plant will be for feedstock, electricity, gasoline, natural gas, water, chemicals, enzymes, yeast, management, and administration. The price and quantity of each input used will be necessary to calculate the ethanol plant expenses.

The price per ton of sweet sorghum will be calculated in the farm model based on a constant contract price for each study area. Random prices for electricity, gasoline, and natural gas inputs will be simulated using the MVE distribution (42-44).

(42) $\tilde{P}_{elec}=\hat{P}_{elec}*[1+MVE(S_i,F(S_i),C_{elec})]$

(43) $\tilde{P}_{gas}=\hat{P}_{gas}*[1+MVE(S_i,F(S_i),C_{gas})]$

(44) $\tilde{P}_{ngas}=\hat{P}_{ngas}*[1+MVE(S_i,F(S_i),C_{ngas})]$

A deterministic water price will be based on the price set by the water district in each study area. The deterministic price for chemicals, enzymes, yeast, maintenance, labor, management, administration, miscellaneous inputs, and sweet sorghum and sweet sorghum alcohol processing will come from Bryan and Bryan Iternational (2004), adjusted for inflation.

Electricity used by the plant will be a function of the type and amount of feedstock processed. The quantities of sweet sorghum and corn to be processed were calculated in Equations 21 and 22. The total quantity of sweet sorghum used ($\tilde{T}Q_{ss}$) will be multiplied by the technical coefficient for electricity used (CF_{sselec}) to simulate the quantity of electricity required to produce alcohol from sweet sorghum ($\tilde{Q}_{sselec}$) (45).

(45) $\tilde{Q}_{sselec}=\tilde{T}Q_{ss}*CF_{sselec}$

The electricity used to produce corn alcohol will be calculated in the same manner as the electricity used to produce sweet sorghum alcohol (46).

(46) $\tilde{Q}_{cornelec}=\tilde{T}Q_{cornalc}*CF_{cornelec}$

The total quantity of electricity ($\tilde{T}Q_{elec}$) purchased will equal the electricity used to produce corn alcohol (47) ($\tilde{Q}_{cornelec}$).

(47) $\tilde{T}Q_{elec}=\tilde{Q}_{cornelec}$

The total quantity of gasoline ($\tilde{T}Q_{gas}$) used as a denaturant will be the product of the total quantity of alcohol produced ($\tilde{T}Q_{alc}$) and the denaturant coefficient ($CF_{denaturant}$) (48).

(48) $\tilde{T}Q_{gas}=\tilde{T}Q_{alc}*CF_{denaturant}$

Natural gas ($\tilde{T}Q_{ngas}$) will be used to make steam when processing corn and will be a function of the total quantity of corn alcohol produced ($\tilde{T}Q_{cornalc}$) and the coefficient for natural gas used (CF_{ngas}) (49).

(49) $\tilde{T}Q_{ngas}=\tilde{T}Q_{cornalc}*CF_{ngas}$

Water will be used to process the sweet sorghum and corn. The total quantity of sweet sorghum ($\tilde{T}Q_{ss}$) multiplied by the amount of water used per ton of sweet sorghum crushed ($CF_{sswater}$) will simulate the quantity of water required ($\tilde{Q}_{sswater}$) to process the stalks (50).

(50) $\tilde{Q}_{sswater}=\tilde{T}Q_{ss}*CF_{sswater}$

The water used to produce corn alcohol will be based on the total quantity of corn alcohol produced ($\tilde{T}Q_{cornalc}$) and the water per gallon of corn alcohol coefficient ($CF_{cornwater}$) (51).

(51) $\tilde{Q}_{cornwater}=\tilde{T}Q_{cornalc}*CF_{cornwater}$

The total quantity of water used to produce corn and sweet sorghum alcohol ($\tilde{T}Q_{water}$) will be the sum of the water used for each feedstock (52).

(52) $\tilde{T}Q_{water}=\tilde{Q}_{sswater}+\tilde{Q}_{cornwater}$

The variable cost of each input ($\tilde{V}C$) will be the product of the input price and quantity used (53-57).

(53) $\tilde{V}C_{ss}=P_{ss}*\tilde{T}Q_{ss}$

(54) $\tilde{V}C_{corn}=\tilde{P}_{corn}*\tilde{T}Q_{corn}$

(55) $\tilde{V}C_{gas}=\tilde{P}_{gas}*\tilde{T}Q_{gas}$

(56) $\tilde{V}C_{ngas}=\tilde{P}_{ngas}*\tilde{T}Q_{ngas}$

(57) $\tilde{V}C_{water}=P_{water}*\tilde{T}Q_{water}$

The variable cost of chemicals, enzymes, yeast, maintenance, labor, management, administration, miscellaneous costs, and sweet sorghum and sweet sorghum alcohol processing will be stochastic based on the amount of feedstock used or alcohol or ethanol produced. Chemicals, yeast, and enzymes are used to produce corn alcohol, thus the variable cost ($\tilde{V}C$) will be the product of the deterministic price for each input (P) and the quantity of corn alcohol produced ($\tilde{Q}_{cornalc}$) (58-60).

(58) $\tilde{V}C_{chemicals}=P_{chemicals}*\tilde{Q}_{cornalc}$

(59) $\tilde{V}C_{enzymes}=P_{enzymes}*\tilde{Q}_{cornalc}$

(60) $\tilde{V}C_{yeast}=P_{yeast}*\tilde{Q}_{cornalc}$

Deterministic prices for maintenance, labor, management, administration, and miscellaneous inputs to produce corn alcohol will be multiplied by the quantity of corn alcohol produced ($\tilde{Q}_{cornalc}$) (61-65).

(61) $\tilde{V}C_{maint}=P_{maint}*\tilde{Q}_{cornalc}$

(62) $\tilde{V}C_{labor}=P_{labor}*\tilde{Q}_{cornalc}$

(63) $\tilde{V}C_{mngt}=P_{mngt}*\tilde{Q}_{cornalc}$

(64) $\tilde{V}C_{cornadmin}=P_{cornadmin}*\tilde{Q}_{cornalc}$

(65) $\tilde{V}C_{misc}=P_{misc}*\tilde{Q}_{cornalc}$

Deterministic prices (P) for feedstock and alcohol processing and administrative costs for sweet sorghum will be multiplied by the quantity of sweet sorghum used

($\tilde{T}Q_{ss}$) and sweet sorghum alcohol produced ($\tilde{T}Q_{ssalc}$) to calculate the variable processing and administrative costs ($\tilde{V}C_{n}$) (66-68).

(66) $\tilde{V}C_{ssproc}=P_{ssproc}*\tilde{T}Q_{ss}$

(67) $\tilde{V}C_{ssalcprocessing}=P_{ssalcprocessing}*\tilde{T}Q_{ssalc}$

(68) $\tilde{V}C_{ssadmin}=P_{ssadmin}*\tilde{T}Q_{ssalc}$

The total variable cost to produce ethanol ($\tilde{T}VC$) will be the sum of the variable costs per input ($\tilde{V}C$) (69).

(69) $\tilde{T}VC_{n}=\tilde{V}C_{ss}+\tilde{V}C_{corn}+\tilde{V}C_{gas}+\tilde{V}C_{ngas}+\tilde{V}C_{water}+\tilde{V}C_{chemicals}+\tilde{V}C_{enzymes}+\tilde{V}C_{yeast}+\tilde{V}C_{maint}$
$+\tilde{V}C_{labor}+\tilde{V}C_{mgnt}+\tilde{V}C_{cornadmin}+\tilde{V}C_{misc}+\tilde{V}C_{ssproc}+\tilde{V}C_{ssalcproc}+\tilde{V}C_{ssadmin}$

The cost to start up the boilers will be fixed annually. The startup cost will cover the cost of natural gas and other miscellaneous inputs to start grinding sweet sorghum each season. The sum of the startup costs and the total variable costs make up the total annual cost of production.

Cash Reserves, Loans, and Inflation Rates

Interest costs will be calculated for cash reserves, the operating and cash flow deficit loans, and the land and refinery loan. Beginning cash in 2008 will be zero so no savings interest will be accrued in the first year. Beginning cash in 2009 ($\tilde{B}C_{09}$) multiplied by the 2009 savings interest rate ($IR_{sv;09}$) will simulate earned interest in 2009 ($\tilde{E}I_{09}$) (70). Equation 70 will be repeated for each year in the model.

(70) $\tilde{E}I_{09}=\tilde{B}C_{09}*IR_{sv;09}$

The operating loan interest cost accrued in 2008 ($\tilde{O}LI_{08}$) will be the product of the total variable cost ($\tilde{T}VC_{08}$), the fraction of the year interest is paid on the operating loan line of credit (LF), and the forecasted national interest rate in 2008 ($IR_{op;08}$) plus a risk premium (RP) (71).

(71) $\tilde{O}LI_{08}=\tilde{T}VC_{08}*LF*(IR_{op;08}+RP)$

The operating loan principal ($\tilde{O}LP_{08}$) will be equal to the total variable costs ($\tilde{T}VC_{08}$) incurred each year. The operating principal and interest will be paid annually.

The interest accrued on the cash deficit loan will be zero in 2008. Interest on cash flow deficits in 2009 ($\tilde{D}LI_t$) will be calculated by multiplying the cash flow deficit in 2008 ($\tilde{C}D_{t-1}$) by the 2009 interest rate for deficit loans ($IR_{dl;t}$) plus a risk premium (RP) (72). Equation 72 will be used in 2009 through 2017.

(72) $\tilde{D}LI_t=\tilde{C}D_{t-1}*(IR_{dl;t}+RP)$

The land and building loan interest ($L\&BI$) will be calculated based on the remaining debt ($L\&B_{debt}$) and fixed interest rate ($IR_{L\&B}$) (73).

(73) $L\&BI_t=L\&B_{debt;t}*IR_{L\&B}$

A fixed payment amount will be calculated for the land and building loan based on the length of the loan, amount borrowed, and a fixed interest rate. The annual land and building principal payment (PP) will be the difference between the fixed annual payment (AP) and the interest owed ($L\&BI$) (74).

(74) $PP_t=AP-L\&BI_t$

Annual taxes for the land and structures will be based on the tax rate in each study area and the initial value of the land and buildings. The value of the land (L_{08}) and buildings (Bld_{08}) in 2008 multiplied by the tax rate (R_{taxes}) will simulate the annual property taxes paid each year (Tx_n) (75).

(75) $Tx_n=(L_{08}+Bld_{08})*R_{taxes}$

Deterministic inflation forecasts will be applied to the cost of fuel, energy, supplies, repairs, machinery, wages, and taxes through 2017 (76-83). The equations are demonstrated for 2009.

(76) $\tilde{P}_{gas;09}=\tilde{P}_{gas;08}*(1+Inf_{fuel;08})$

(77) $\tilde{P}_{ngas;09}=\tilde{P}_{ngas;08}*(1+Inf_{fuel;08})$

(78) $\tilde{P}_{elec;09}=\tilde{P}_{elec;08}*(1+Inf_{fuel;08})$

(79) $\tilde{P}_{supplies;09}=\tilde{P}_{supplies;08}*(1+Inf_{supplies;08})$

(80) $\tilde{P}_{repairs;09}=\tilde{P}_{repairs;08}*(1+Inf_{repairs;08})$

(81) $\tilde{P}_{machinery;09}=\tilde{P}_{machinery;08}*(1+Inf_{machinery;08})$

(82) $\tilde{P}_{wages;09}=\tilde{P}_{wages;08}*(1+Inf_{wages;08})$

(83) $\tilde{P}_{taxes;09}=\tilde{P}_{taxes;08}*(1+Inf_{taxes;08})$

Total annual expenses ($\tilde{T}C_t$) for the ethanol plant will be the sum of the total variable costs ($\tilde{T}VC_t$), annual fixed start up cost (SU), interest on loans $(\tilde{D}LI_t+\tilde{O}LI_t+L\&BI_t)$, and property taxes (Tx_t) (84).

(84) $\tilde{T}C_t=\tilde{T}VC_t+SU+\tilde{D}LI_t+\tilde{O}LI_t+L\&BI_t+Tx_t$

Net cash income ($\widetilde{NCI}_t$) for the ethanol plant will equal the total receipts ($\widetilde{TR}_t$) minus the total cost ($\widetilde{TC}_t$) to produce and sell ethanol each year (85).

(85) $\widetilde{NCI}_t=\widetilde{TR}_t-\widetilde{TC}_t$

Net cash income ($\widetilde{NCI}_t$) minus depreciation (Dep_t) will simulate net income ($\widetilde{NI}_t$) each year (86).

(86) $\widetilde{NI}_t=\widetilde{NCI}_t-Dep_t$

Total assets ($\widetilde{TA}_t$) will be the sum of the value of the land (L) and the buildings or structures (Bld_t) plus any cash reserves ($\widetilde{CR}_t$) (87). The value of the buildings will be depreciated using the straight line method through 2017.

(87) $\widetilde{TA}_t=L+Bld_t+\widetilde{CR}_t$

Total liabilities ($\widetilde{TL}_t$) will be the sum of the deficit cash ($\widetilde{DLD}_t$) and the land and building loan debt ($L\&BD_t$) (88).

(88) $\widetilde{TL}_t=\widetilde{DLD}_t+L\&BD_t$

Ending net worth ($\widetilde{ENW}_t$) each year will be equal to total assets ($\widetilde{TA}_t$) minus total liabilities ($\widetilde{TL}_t$) (89).

(89) $\widetilde{ENW}_t=\widetilde{TA}_t-\widetilde{TL}_t$

Key Output Variables (KOVs)

Annual ending cash (EC) and net present value (NPV) will be the KOVs in the ethanol model. Each KOV will be calculated using the values from the income statement, cash flows, and balance sheet.

Total cash inflows ($\tilde{T}R_t+\tilde{B}C_t+\tilde{E}I_t$) minus total cash outflows ($\tilde{T}C_t$) will simulate the annual ending cash ($\tilde{E}C_t$) (90).

(90) $\tilde{E}C_t=(\tilde{T}R_t+\tilde{B}C_t+\tilde{E}I_t)-\tilde{T}C_t$

Positive annual ending cash 80% or more of the time will indicate economic success.

Present value of ending net worth and net present value are the only variables that estimate profitability over multiple years in 2008 dollars. The present value of ending net worth ($\tilde{P}VENW_{17}$) will be the product of the ending net worth in 2017 ($\tilde{E}NW_{17}$) and discount factor in 2017 (DF_{17}) (91). Dividends would typically be considered in the PVENW, but because of the financing structure (100% financing), dividends will not be paid.

(91) $\tilde{P}VENW_{17}=\tilde{E}NW_{17}*DF_{17}$

Net present value ($\tilde{N}PV$) will be a function of beginning net worth (BNW_{08}) and the present value of ending net worth ($\tilde{P}VENW_{17}$). Beginning net worth will be equal to the beginning value of the land and buildings bought ($L_{07}+Bld_{07}$) (92).

(92) $BNW_{08}=L_{07}+Bld_{07}$

Net present value will be calculated by multiplying beginning net worth (BNW_{08}) by negative one (-1) and adding the present value of ending net worth ($\tilde{P}VENW_{17}$) (93).

(93) $\tilde{N}PV=[BNW_{08}*(-1)]+\tilde{P}VENW_{17}$

Making ethanol from sweet sorghum juice will be considered an economic success if the net present value is positive.

Chapter IV presented and explained the equations and variables that will be used in the farm model and ethanol model to determine the feasibility of producing ethanol from sweet sorghum juice in Texas. Chapter V will outline the model parameters and validation.

CHAPTER V

MODEL PARAMETERS AND VALIDATION

Control variables, assumptions, parameters, and validation for the farm model and ethanol model are discussed in the following section. The farm model control variables, assumptions, and parameters pertain to farm program rates and prices, simulated crop prices, and inflation rates for fuel and fertilizer. The ethanol model deals specifically with the capacity and operation of the ethanol plant, prices and costs of feedstocks and byproducts, sweet sorghum growing and yield parameters, as well as financial assumptions over a 10 year planning horizon. Explanations for each of the control variables are detailed in this chapter starting with those used in the farm model.

Farm Model Control Variables, Parameters, and Assumptions

Crop prices and yields, farm program payment rates and prices, and inflation wedges all serve as control variables, parameters, and assumptions in the farm model and are explained in the same order.

Simple regression analysis is used to project the local Texas price for each crop being modeled (Table 5). The national projected 2008 crop prices are provided by FAPRI. Adjustments are made to FAPRI prices to reflect observed 2008 mean market prices. The average pre-scaled and post-scaled 2008 national prices for each crop are listed in Table 5. Historical Texas prices provided by NASS are regressed on historical national prices from USDA-NASS to estimate the slope and intercept for each crop price. The intercept and slope coefficients are used in conjunction with the scaled national FAPRI prices to simulate the localized prices for 2008. The stochastic Texas crop prices are used to simulate revenue for a farmer growing corn, cotton, grain sorghum, rice, or wheat.

Table 5. Regression Analysis Output and Average 2008 National and Texas Crop Prices for the Farm Model

Historical Crop Price Simple Regression	Corn	Cotton	Sorghum	Rice	Wheat
Intercept	0.508	-0.065	1.016	-0.291	-0.437
Slope	0.899	1.022	1.415	1.084	1.096
R-Square	0.841	0.810	0.709	0.861	0.860
T-Test	11.489	6.857	7.813	12.445	12.380
Prob(T)	1.1E-11	1.8E-05	2.7E-08	1.9E-12	2.1E-12
Pre-Scaled Average National Prices[a]	3.90	0.65	10.53	3.53	5.29
Post-Scaled Average National Prices	5.97	0.71	11.05	5.40	8.09
Average Texas Prices	6.42	0.51	8.33	9.25	8.59

Source[a]: FAPRI 2008

Sweet sorghum and competing crop yields in each study area are simulated by CroPMan (Harman 2007) between 1960 and 2006 using actual weather data for each of the four study areas. The CroPMan yields are used to estimate the parameters for an MVE distribution in each study area. CroPMan yields (1960-2006) for selected crops in the four study areas are in Appendix A. The MVE distribution is used to simulate the different regions’ crop yields for 2008. The 2008 crop yields are used in the farm model

Table 6. Average Annual Sweet Sorghum Yields for Each Study Area

	Willacy Co.*	Wharton Co.*	Hill Co.*	Moore Co.*
		(tons/acre)		
Sweet Sorghum Yield	137.32	47.08	33.06	30.00

Note: County (Co.)

Table 7. Farm Program Payment Rates and Prices for the 2002 Farm Bill[a]

	Direct Payment Rate	Target Price	Loan Rate
		$/unit	
Corn (bu)	0.28	2.63	1.95
Cotton (lb)	0.07	0.72	0.52
Sorghum (bu)	0.35	2.57	1.95
Rice (cwt)	2.35	10.50	6.50
Wheat (bu)	0.52	3.92	2.75

Note: Bushel (bu), Pound (lb), Hundred Weight (cwt); Source[a]: USDA, 2002 Farm Bill

budgets to calculate receipts and costs. The average annual sweet sorghum yields for the study areas are summarized in Table 6.

Farm program payment rates and prices specified in the 2002 Farm Bill are available from the USDA (Table 7). Government payments are calculated based on the payment rates, payment yield, base acres, national prices, and stochastic crop yields in each study area (Table 8). Base pay acres for farms modeled are assumed to be equal to those on representative Texas farms developed by the Herbst et al. Farm subsidy payments are included in the net returns.

Table 8. 2008 Farm Program Payment Yield and Base Acres on Four Representative Farms in Texas[a]

County	Direct Payment Yield	Counter Cyclical Payment Yield	Base Pay Acres
	unit/acre	$/unit	
Moore			
Irrigated Wheat (bu)	40.00	41.00	1,500
Grain Sorghum (cwt)	51.00	51.00	300
Grain Sorghum (bu)	91.07	91.07	300
Irrigated Corn	119.00	150.00	1,200
Hill			
Grain Sorghum (cwt)	35.00	46.70	1,200
Grain Sorghum (bu)	62.50	83.39	1,200
Cotton	375.00	467.00	400
Wheat	29.00	39.00	200
Corn	70.00	94.00	200
Wharton			
Rice	60.00	60.00	1,280
Willacy			
Irrigated Cotton	550.00	550.00	590
Grain Sorghum (cwt)	36.40	36.40	1,978
Grain Sorghum (bu)	65.00	65.00	1,978
Fraction of Government Subsidy Paid to Farmers			0.85

Note: Bushel (bu), Pound (lb), Hundred Weight (cwt)
Source[a]: Herbst et al. 2007

Selected input costs reported in AFPC representative farm budgets (Herbst et al. 2007) are inflated to better represent the 2008 input costs at the farm level (Table 9). The costs of inputs such as fuel, seed, herbicide, insecticide, wages, and fertilizer have increased since the budgets were developed in 2007. An average fertilizer inflation rate is used to inflate all fertilizer costs as quantities and prices for each fertilizer were not specified in the budgets. Inflation rates provided by FAPRI are used for all other selected input costs and included in the 2008 farm budgets for each study area.

Table 9. Inflation Rates for Selected Input Costs[a]

Input Cost	Rate
Fuel	12%
Seed	5%
Herbicide	0.3%
Insecticide	4%
Wages	3%
Average Fertilizer Cost Increase	32%

Source[a]: FAPRI, January 2008 Baseline

The itemized crop budget used to calculate the net returns for rice and sweet sorghum in Wharton County is shown in Table 10. The budgets for the remaining study areas and a summary table of the receipts, costs, and yields for the crops in each study area can be found in Appendix A. The sweet sorghum budgets assume the operating loan structure (fraction of year interest is paid and operating interest rate) is the same as other crops on the farm.

The control variables, assumptions, and parameters in the farm model will have a direct effect on the total costs and net returns for crops modeled in each study area, thus affecting the price of sweet sorghum that the ethanol plant must pay to produce ethanol from sweet sorghum juice.

Table 10. Itemized Costs in the 2008 Budget for a Sweet Sorghum Farm in Wharton County

	Rice (cwt)[a]	Sweet Sorghum (ton)[b]
	$/acre	
Variable Costs		
Seed	33.65	11.67
Fertilizer	133.30	103.21
Herbicides	106.83	20.42
Insecticides	16.00	19.60
Irrigation	72.69	-
Other Production	77.84	-
Drying, Hauling, etc.	217.99	-
Crop Insurance Premiums	-	-
Main Crop Variable Cost	658.29	154.90
Total Variable Costs	658.29	154.90
Overhead Costs		
Rent	72.27	45.00
Labor	123.26	-
Maintenance and Repairs	102.47	-
Accounting & Legal	4.23	-
Fuel & Lube	52.28	42.16
Utilities	4.32	-
Insurance	8.48	-
Miscellaneous	1.33	-
Fraction of Year Interest Paid	0.20	0.20
Operating Interest Rate	9%	9%
Depreciation	13.01	22.31
Total Overhead Costs	381.94	87.16

Note: Bushel (bu), Pound (lb), Hundred Weight (cwt)
Source[a]: Herbst et al. 2007
Source[b]: Rooney 2007

Ethanol Model Control Variables, Parameters, and Assumptions

The ethanol model has numerous control variables, assumptions, and parameters for alcohol production, feedstock processing, byproduct outputs, input costs, financial structure, and forecasted prices, costs, and inflation rates. The economic feasibility of producing ethanol from sweet sorghum juice in Texas will be based on the costs incurred and revenue gained by operating within the parameters discussed in this section.

Assumptions for the ethanol plant capacity and ethanol production set the foundation for the feasibility study in each area given two different operating scenarios. The first alternative analyzes ethanol production using only sweet sorghum as the feedstock while the second scenario analyzes production using sweet sorghum and corn. Total ethanol produced under both scenarios is simulated for each area based on the sweet sorghum contract acres, control variables for producing alcohol from sweet sorghum and corn, and the number of days the plant produces ethanol (Table 11).

Production assumptions vary across alternatives and study areas. Ethanol capacity is greater in scenario two versus scenario one in all study areas because corn can be used when sweet sorghum is out of season. The alcohol produced from sweet sorghum and the tons harvested do not change from each alternative because the maximum quantity of sweet sorghum is being utilized in both situations. The number of days sweet sorghum is used depends on the average number of days without a freeze in each area. Willacy County is farthest South and has the most days without a freeze so it has the longest sweet sorghum growing season. Moore County is farthest North and has

Table 11. Ethanol Plant Operating Assumptions Using Sweet Sorghum or Sweet Sorghum and Corn to Produce Ethanol in Each Study Area

	Willacy County		Wharton County		Hill County		Moore County	
	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn
				MMGY				
Ethanol Plant Capacity	34.00	56.50	22.00	54.00	20.00	59.00	13.60	64.50
Total Annual Ethanol Production	34.00	56.50	22.00	54.00	20.00	59.00	13.60	64.50
Ethanol from Sweet Sorghum (gallons)	34.00	34.00	22.00	22.00	20.00	20.00	13.60	13.60
Ethanol from Corn (gallons)	-	22.50	-	32.00	-	39.00	-	50.90
Ethanol per Day (million gallons)	0.10	0.17	0.07	0.17	0.06	0.18	0.04	0.20
Average Total Gallons Alcohol Produced (million gallons)	34.82	57.16	23.92	57.16	17.94	57.16	6.33	57.16
Alcohol from Sweet Sorghum (million gallons)	34.82	34.82	23.92	23.92	17.94	17.94	6.33	6.33
Alcohol from Corn (million gallons)	-	22.34	-	33.24	-	39.22	-	50.83
Days Sweet Sorghum Used	198	198	136	136	102	102	36	36
Gallons of Alcohol per Bushel of Corn		2.73		2.73		2.73		2.73
Days Plant is Not Producing Ethanol	40	40	40	40	40	40	40	40
Percent of Denaturant Added to Alcohol	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025

Note: Sweet Sorghum (SS), Million Gallons per Year (MMGY) the fewest frost free days and uses sweet sorghum the fewest number of days. The quantity of corn used to produce ethanol is inversely related to the quantity of sweet sorghum used. Corn utilization is greater towards the North (Moore and Hill Counties) and less in the South (Willacy and Wharton Counties). A corn conversion ratio of 2.73 gallons of alcohol per one bushel of corn is assumed. The plant will not operate for 40 days to clean and repair the ethanol facilities. Of the total amount of ethanol produced, 2.5% of it is gasoline as the denaturant.

Control variables and coefficients used in the sweet sorghum alcohol production model are listed in Table 12. It is assumed that 1% of the harvested sweet sorghum will be lost between the field and the mill. The maximum daily grinding capacity, 11,111 tons, is based on grinding capacity of the mill priced by Dedini (2007) and typical for efficient sugarcane processing. Seventy percent wet matter content per ton of harvested sweet sorghum is in line with estimates and field trials (Rooney 2007, Blumenthal 2007).

Table 12. Sweet Sorghum Processing Coefficients for an Ethanol Refinery

Variable	Coefficient
Sweet Sorghum Loss Fraction	1%
Maximum Tons Crushed per Day[a]	11,111
Bagasse per Ton of Processed Sweet Sorghum[a] (lbs)	580
Wet Matter per Sweet Sorghum Ton[b]	70%
Squeezing Efficiency of Juicing Press[b]	97%

Note: Pounds (lbs)
Source[a]: Dedini, 2007
Source[b]: TAR, 2007

Ninety-seven percent squeezing efficiency of the juicing press is the standard for large scale sugarcane processing facilities (Rooney 2007, Blumenthal 2007).

Alternative two assumes that corn is used to achieve maximum operating capacity when sweet sorghum is not available (Table 13). The cost of a storage facility for storing seven days worth of corn is included in the ethanol model cost to insure against corn delivery interruptions. It will cost approximately $0.20 per bushel to store the corn. The average number of days corn will be used to produce alcohol is based on the average number of days per year without a freeze in each study area minus the number of days sweet sorghum is used to produce alcohol and minus the number of days the refinery is not operating. Corn will be used on average for 127, 189, 223, and 289 days in Willacy, Wharton, Hill, and Moore Counties, respectively. It is assumed the refinery will not operate for 15 days between sweet sorghum and corn and 15 days between corn and sweet sorghum to allow time to clean the plant. An additional 10 days of down time is expected for unscheduled repairs and operating disruptions.

Processing sweet sorghum for ethanol is assumed to be similar to Brazilian alcohol refineries processing sugarcane. There is an average of 15.8 gallons of alcohol per ton of recoverable sugar in sweet sorghum based on Rooney's (2007) field results and the formula for making alcohol from sugar. The percent of wet matter in sweet sorghum, squeezing efficiency of the rollers, and the coefficients used to process sugarcane are variables used to calculate total alcohol produced from sweet sorghum.

Table 13. Corn Processing Assumptions for Each Study Area

	Willacy	Wharton	Hill	Moore
Corn Needed per Year (thousand bushels)	8,181	12,175	14,366	18,617
Corn Used per Day (thousand bushels)	64.42	64.42	64.42	64.42
Corn Storage (7 days worth; thousand bushels)	450.94	450.94	450.94	450.94
Corn Storage Cost ($/bushel)[a]	0.20	0.20	0.20	0.20
Average Days Corn Used	127	189	223	289

Source[a]: Shane Springs Construction, Inc., 2008

An estimated 40 lbs. of WDGS will be produced per bushel of corn processed, and will be sold to local farms and animal feeding operations (Table 14). The selling price for WDGS at an ethanol refinery in Portales, New Mexico is used as a benchmark for the price in Texas. Equations 19 and 20 detail the calculations made to simulate the 2008-2017 Texas WDGS prices.

Parameters for Brix, the vinasse price, and the average number of days without a freeze were necessary. The Brix percentage is an indicator of the sugar content in sweet sorghum and therefore is a variable in determining how much ethanol can be produced

Table 14. Variables for Wet Distillers Grains with Solubles

	Coefficients
WDGS per Bushel of Corn (wet lbs/bu)[a]	40
WDGS per Bushel of Corn (dry lbs/bu)	64
Price for WDGS ($/wet ton)[b]	60.00

Note: Wet Distillers Grains with Solubles (WDGS), Pounds (lbs), Bushels (bu)
Source[a]: Tiffany and Eidman, 2003
Source[b]: Gruhlkey, 2007

from sweet sorghum. Brix percentages tend to vary widely across different sweet sorghum varieties and are simulated with a GRKS distribution using these parameters: a minimum of 12%, a mean of 14%, and a maximum of 16% (Rooney 2007).

The selling price for vinasse is simulated using the GRKS distribution with a minimum, mean, and maximum of 30, 35, and 40 based on an industry expert's estimate (Anderson 2008). Weather data collected by NOAA was analyzed to simulate the number of days without a freeze in each study area. The minimum, mean, maximum, and standard deviation for the number of days without a freeze define the parameters used in the truncated normal distribution to simulate the sweet sorghum growing period each year (Table 15).

Table 15. Parameters for Additional Stochastic Variables in the Ethanol Model

	Minimum	Mean	Maximum	Standard Deviation
Vinasse Price ($/ton)[a]	30	35	40	
Number of Days without a Freeze[b]				
Willacy	232	303	365	31.0156
Wharton	205	243	293	20.8720
Hill	192	225	286	19.3769
Moore	129	171	194	15.1038

Source[a]: Anderson, 2008
Source[b]: NOAA, 2007

The number of growing days between harvests for sweet sorghum and the percent yield of second and third cuts in comparison to the first cut is based on field trial experience with grain sorghum (Rooney 2007, Blumenthal 2007) (Table 16). Willacy

County is assumed to require the fewest growing days while sweet sorghum in Moore County requires the most growing days due to the average temperatures in each study area.

Table 16. Number of Growing Days between Harvests and Percent of Yield Second and Third Harvests Compared to First Cut Yields for the Four Study Areas[a]

County	Between Planting and First Cut	Between First Cut and Second Cut	Between Second Cut and Third Cut	Second Cut Compared to First Cut	Third Cut Compared to First Cut
	--(Average Number of Days)--			--(Percent Yield)--	
Willacy	105	60	60	70%	50%
Wharton	107	77	77	70%	50%
Hill	123	90	90	70%	50%
Moore	135	90	90	70%	50%

Source[a]: Rooney 2007; Blumenthal 2007

French's (1960) transportation cost formula, current hauling costs (as reported by the U.S. Custom Harvesters, Inc. in 2008), and farmable acreage are used to calculate the hauling cost in each study area based on a three year rotation (Table 17). French's (1960) transportation cost formula assumes a square road and field layout. Fifty percent of the farmable land in each study area is assumed to be available for sweet sorghum production. The hauling costs to the ethanol mill are estimated at $0.33 per ton per mile (Table 17).

The ethanol plant will use custom harvesting services to harvest and haul the sweet sorghum from the field to the plant. The harvest rate is $6.35 per ton and the hauling rate is $0.33 per ton per mile based on rates charged by select U.S. Custom Harvesters, Inc. members (2008).

Table 17. Variables to Calculate Hauling Costs per Year for Each Study Area Based on a Three Year Field Rotation of Sweet Sorghum

	Willacy	Wharton	Hill	Moore
Percent of Farmable Land[a]	0.604	0.615	0.478	0.478
Percent of Farmland with Sweet Sorghum	0.50	0.50	0.50	0.50
Years in Crop Rotation	3	3	3	3
Variable Cost per Ton per Mile[b]	0.33	0.33	0.33	0.33

Source[a]: NASS, 2007
Source[b]: U.S. Custom Harvesters, Inc., 2008

Costs to construct a sweet sorghum ethanol plant are based on Dedini's (2007) estimates for manufacturing, transporting, site preparation, and assembling a sugarcane to ethanol plant (Table 18). The plant has the capacity to grind 11,111 tons of stalks or billets per day. Two boilers, generators, and smoke emission scrubbers are built into the budget so ethanol production can continue in the event of a breakdown in one of the boiler/generators. The estimated cost to transport the equipment from the manufacturer is five percent of the total value of the equipment. Due to the chemical nature of ethanol and vinasse, specialized storage tanks are used. When each gallon of vinasse is reduced to approximately 50% solids, it is assumed to be half the cost of storing one gallon of ethanol, however for every one gallon of sweet sorghum alcohol produced, 12 gallons of vinasse are produced as a byproduct. Storage of 6 million gallons of ethanol and 36 million gallons of vinasse (50% solids) costing $0.20 per gallon are included in the equipment plant costs.

An ethanol refinery in Moore County will deviate from the refineries in the other four study areas. A smaller sweet sorghum handling system, one boiler, generator, and scrubber, a smaller vinasse drier, and a lower cost to assemble the plant were considered to be more suitable to the production environment in Moore County (Table 18).
The costs for the corn processing equipment are based on industry estimates (Table 19). Corn storage by rule of thumb is $2 per bushel storage capacity. Corn storage that

Table 18. Cost of Equipment and Plant Setup for a Sweet Sorghum Ethanol Production Facility in Texas

	All Other	Moore[c]
Equipment Expense	$/Unit	
Sweet Sorghum Handling Equipment	5,000,000	2,500,000
Sweet Sorghum Rollers and Juice Collection	52,800,000	52,800,000
Fermentation and Distillation Equipment	10,000,000	10,000,000
Boiler and Generator 1	15,000,000	7,500,000
Boiler and Generator 2	15,000,000	-
Smoke Emission Scrubber 1	20,000,000	20,000,000
Smoke Emission Scrubber 2	20,000,000	-
EPA Vinasse Drier	20,000,000	5,000,000
Transportation of Plant Materials	3,140,000	3,140,000
Land Preparation	25,000,000	25,000,000
Plant and Building Assembly	60,000,000	30,000,000

Note: Estimated as approximately half the cost of storing ethanol when vinasse is 50% solids.
Source[a]: Dedini, 2007

Table 19. Cost of Corn-Specific Equipment Added to a Sweet Sorghum Ethanol Plant in Texas[a]

Equipment Expense	$
Grain Storage	8,000,000
Receiving, Auger, and Grinding Equipment	3,500,000
Sum	11,500,000

Source[a]: Shane Springs Construction, Inc., 2008

accommodates 500,000 bushels is assumed in the corn equipment costs. Costs for the receiving area, auger system, and grinding equipment for a facility that can process over 480,000 bushels of corn per day are approximately $3.5 million (Shane Springs Construction 2008). The corn equipment cost will be in addition to the sweet sorghum facility costs when analyzing scenario two (sweet sorghum and corn ethanol production) in each study area.

Water and electricity input coefficients are adapted from Brazilian sugarcane alcohol refineries. Initially, 124 gallons of water is used to process a ton of sweet sorghum—60 gallons during the squeezing stage and 64 for the distillation and fermentation stage (COSAN 2007). Water captured from the vinasse and during distillation is recycled through the plant; therefore approximately 20 gallons of additional water must be purchased per ton of sweet sorghum processed after the initial tons of sweet sorghum are processed. Sweet sorghum alcohol production yields 0.70 kwh of electricity per ton of bagasse burned in a boiler to produce steam and electricity. Processing the sweet sorghum into ethanol uses 0.16 kwh per ton, leaving a surplus of electricity for sale.

Water to process corn will be an additional cost to the ethanol refinery when analyzing scenario two (Table 20). Advanced technology has made it possible to use fewer gallons of water in newer, more efficient corn ethanol refineries. The same costs will be applied to the water purchased for processing sweet sorghum.

Table 20. Water Use and Cost to Process Corn for Ethanol Production in Each Study Area

	Willacy	Wharton	Hill	Moore
Water to Produce Corn Ethanol (gal/gal)[a]	4.00	4.00	4.00	4.00
Variable Cost of Water ($/gal)[b,c,d,e]	0.00185	0.00274	0.00510	0.00160

Note: Gallon (gal)
Source[a]: Committee on Water Implications of Biofuels Production in the U.S. and National Research Council
Source[b]: City of Raymondville, 2008
Source[c]: City of Wharton, 2008
Source[d]: City of Hillsboro, 2008
Source[e]: City of Dumas, 2008

Vinasse output coefficients from COSAN of Brazil (2007) are used to analyze the quantity of vinasse produced from sweet sorghum (Table 21). For every one gallon of sweet sorghum alcohol produced, there are 12 gallons of vinasse produced. Vinasse is similar to the consistency of milk, so it is assumed that one gallon of vinasse weighs 8.33 pounds. Vinasse will be stored as 50% solids and sold by the ton to livestock feed processors.

Variable operating costs for the sweet sorghum (scenario one and two) and corn (scenario two only) ethanol refinery are detailed in Tables 22 and 23. Brazilian alcohol

Table 21. Vinasse Coefficients Used in Each Study Area and Scenario

	Coefficients
Vinasse Produced (gal/gal of sweet sorghum alcohol)[a]	12.00
Vinasse Weight (lb/gal of vinasse)[a]	8.33
Solids in Sellable Vinasse (50%)[b]	0.50

Note: Gallon (gal), Pound (lb)
Source[a]: COSAN, 2007
Source[b]: Anderson, 2008

Table 22. Variable Costs to Operate a Sweet Sorghum Ethanol Refinery[a], 2008

	$/gal
Process Sweet Sorghum	0.18
Process Ethanol	0.28
Administrative Costs	0.10
Annual Startup Costs[b]	25,000

Note: Gallon (gal)
Source[a]: Abstracted costs from sugarcane plant budgets in Brazil, COSAN, 2007.
Source[b]: Assumed Approximate Startup Costs.

producer COSAN (2007) estimates costs to be equivalent to $0.18, $0.28, and $0.10 per gallon for processing sweet sorghum, alcohol, and administrative costs, respectively.

The annual startup cost for natural gas and other inputs to begin operating the boilers and producing sweet sorghum ethanol each year is assumed to be $25,000. Operating costs for the corn processing equipment are taken from Bryan and Bryan International (2004) and inflated to reflect the 2008-2017 forecasted costs.

Approximately 40 acres will be required to construct and operate the ethanol plant and storage facilities. The purchase price of land varies across the study areas from $1,500-$4,000 per acre (Table 24). The land will be used for receiving feedstock and inputs, producing ethanol, input and output storage, and transporting outputs to be sold. All prices were provided by area realtors or trends (Texas Chapter of ASFMRA 2007; Weichert Realtors 2008; Windmill Realty 2008).

Table 23. Variable Costs to Operate a Corn Ethanol Refinery, 2008

	$/gal
Enzymes	0.0529
Chemicals	0.0529
Main. Materials	0.0264
Labor	0.0661
Admin. Costs	0.0529
Misc. Costs + Water Treatment	0.0529
	kwh/gal
Electricity Used	0.80

Note: Gallon (gal), Kilowatt Hours (kwh)
Source: Bryan and Bryan International, 2004 (Inflated)

The refinery construction, equipment, and land cost is assumed to be financed 100% (Table 25). Beginning cash as of January 1, 2008 is zero. The refinery equipment, structures, and land value specific to the various study areas will serve as the initial assets in 2008.

The loan to finance the refinery will be based on the cost of the land in each study area plus the refining cost and the scenario analyzed (Table 26). The loan will be

Table 24. Land Cost and Acreage for the Ethanol Refinery in Each Study Area

	Willacy County[a]	Wharton County[b]	Hill County[c]	Moore County[d]
Acres Needed	40	40	40	40
Cost per Acre	3,000	4,000	2,676	1,500

Source[a]: Trends in Texas Rural Land Values for the 2007 year, 2007, http://recenter.tamu.edu/data/rland/ASFMRA07.pdf
Source[b]: Weichert Realtors, 2008
Source[c]: Windmill Realty, 2008

Table 25. Initial Balance Sheet for the Ethanol Model Financial Statements

	Willacy County		Wharton County		Hill County		Moore County	
	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn
Beginning Cash Jan 1, 2008	-	-	-	-	-	-	-	-
Initial Assets	205.80	205.80	205.80	205.80	205.80	205.80	118.80	115.05
Initial Debt	-	-	-	-	-	-	-	-
Initial Net Worth	205.80	205.80	205.80	205.80	205.80	205.80	118.80	115.05

Note: Sweet Sorghum (SS)

Table 26. Terms for Loan to Finance the Plant and Land Loan for an Ethanol Plant

	Willacy County		Wharton County		Hill County		Moore County	
	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn	SS	SS & Corn
Loan Amount (million dollars)	205.80	205.80	205.80	205.80	205.80	205.80	118.80	115.05
Years to Finance Loan	10	10	10	10	10	10	10	10
Interest Rate	12%	12%	12%	12%	12%	12%	12%	12%
Down Payment as a Fraction	-	-	-	-	-	-	-	-

Note: Sweet Sorghum (SS)

financed over ten years with a fixed interest rate of 12%. There is no down payment. Interest and principle payments to the investors will be a proxy for their dividends.

Financial variable assumptions for the ethanol refinery are consistent across study areas and scenarios (Table 27). Annual market value decreases for the plant are 9%. Repairs are expected to cost 1% of the initial equipment value as of 2008. Due to the uncertain nature of ethanol refinery profits, a 2% premium over the prime interest rate will be paid for the operating interest loan. Operating interest will be paid for a portion of the year (approximately two months). A 15% discount rate is used to calculate the present value of ending net worth in 2017 and the net present value for the businesses.

Table 27. Financial Variable Assumptions for the Ethanol Refinery

Annual Loss of Plant Market Value	9%
Annual Replacement/Repair	1%
Localized Risk Premium for Operating Interest	2%
Part of Year Operating Interest Paid	17%
Discount Rate	15%

Average projected prices assumed for 2008-2017 are summarized in Table 28. The Department of Energy provided projections for all of the energy prices with the exception of ethanol and electricity. The projected ethanol prices used in the study are from Bryant (2008). The Energy Information Administration (2008) provided statistics on the purchase and sale price of electricity. Annual corn price projections from FAPRI’s 2008 January Baseline are used for the study. The WDGS mean prices are based on mean prices of corn and soybean meal localized to the market in Texas. There is no current market price for vinasse so an average projected price estimated by an industry professional is used. Projected national inflation rates were provided by FAPRI for 2008 through 2017 (Table 29). Annual production costs for the plant are inflated from their base 2007 values using projected rates of inflation in Table 30. Depreciation rates determined by the Internal Revenue Service are used to depreciate the plant costs, excluding land values, for income tax purposes (Table 30).

The control variables, assumptions, and parameters for the farm model and ethanol model set the foundation for the stochastic analyses. Stochastic simulation analysis is the best method to analyze decisions that involve risk because it uses probability distributions of exogenous variables to calculate a distribution for all possible outcomes (Pouliquen 1970, p. 2); however, the stochastic variables must be validated to ensure that the simulated means reproduce the historical means. The validation results are covered in the following section.

Validation of the Farm Model Stochastic Variables

The farm model stochastic yields must be validated before the analysis can be performed so results can be considered accurate representations of the operating environment for a sweet sorghum farm. Validation results for simulated yields in each study area are presented below.

Stochastic yields for the four study areas were simulated using an MVE distribution. The simulated percent deviations from the mean were applied to the

Table 28. Average Projected Prices Used in the Ethanol Model for 2008-2017

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ethanol ($/gal)[a]	2.45	2.46	2.38	2.41	2.43	2.47	2.54	2.50	2.51	2.52
Electricity Used ($/kwh)[b]	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Green Electricity Sold ($/kwh)	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Gasoline/Denaturant ($/gal)* [b]	2.04	2.08	2.12	2.16	2.20	2.24	2.28	2.32	2.36	2.40
Natural Gas [b]	6.77	6.78	6.78	6.78	6.79	6.79	6.80	6.80	6.81	6.81
Corn ($/bu) [c]	4.65	4.67	4.59	4.70	4.63	4.68	4.72	4.73	4.72	4.74
WDGS ($/ton)	149.64	137.52	132.09	131.01	129.54	128.47	128.72	128.03	125.72	124.24
Vinasse—50% wet ($/ton)	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00

Source[a]: Bryant, 2008
Source[b]: DOE, 2006
Source[c]: FAPRI, 2008
*Volume Price

Table 29. Projected National Inflation Rates for 2008-2017[a]

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Chemicals	0.0168	0.0099	0.0119	0.0125	0.0121	0.0108	0.0177	0.0188	0.0184	0.0169
Fuel	0.1163	-0.0317	-0.0467	-0.0016	-0.0081	-0.0107	0.0013	0.0068	0.0052	0.0065
Supplies	0.0236	0.0161	0.0131	0.0127	0.0130	0.0111	0.0195	0.0224	0.0233	0.0227
Repairs	0.0271	0.0224	0.0240	0.0253	0.0251	0.0241	0.0251	0.0256	0.0255	0.0249
Machinery	0.0221	0.0202	0.0250	0.0274	0.0303	0.0319	0.0378	0.0380	0.0369	0.0352
Building Materials	0.0087	0.0109	0.0174	0.0174	0.0157	0.0131	0.0205	0.0229	0.0235	0.0226
Services	0.0263	0.0256	0.0284	0.0281	0.0288	0.0294	0.0378	0.0401	0.0404	0.0394
Interest	0.0654	0.0698	0.0753	0.0767	0.0778	0.0786	0.0800	0.0816	0.0824	0.0833
Taxes	0.0465	0.0419	0.0338	0.0254	0.0154	0.0122	0.0223	0.0226	0.0224	0.0221
Wages	0.0313	0.0298	0.0273	0.0251	0.0272	0.0277	0.0266	0.0264	0.0260	0.0256
PPI	0.0509	0.0093	0.0154	0.0156	0.0157	0.0140	0.0192	0.0195	0.0193	0.0194

Source[a]: FAPRI, 2008

Table 30. MACRS Depreciation Rates as Specified by the IRS

MACRS Depreciation Rates	10.00%	18.00%	14.40%	11.52%	9.22%	7.37%	6.55%	6.55%	6.56%	6.55%

Note: Modified Accelerated Cost Recovery System (MACRS)
Source: IRS, 2008

Table 31. Validation Tests for Wharton County Crop Yields

Test of Hypothesis for Parameters for Yield Rice

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	82.73	-0.01	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	5.499807	494.11	LB: 439.00 UB: 562.79	0.89	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*

Test of Hypothesis for Parameters for Yield Sweet Sorghum

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	28	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	4.350175	487.96	LB: 439.00 UB: 562.79	0.74	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*

Test Correlation Coefficients

Confidence Level	95.0000%
Critical Value	1.96

	Yield Sweet Sorghum
Yield Rice	1.24

representative farm means to simulate the stochastic yields. The simulated yields were tested against the representative Wharton County farm means (Table 31). Both the rice and sweet sorghum simulated means and standard deviations were statistically equal at the 95% level. Correlation between historical yields and simulated yields was tested. At the 95% level, the correlation between the simulated rice and sweet sorghum yields was the same as observed in the historical yield data. The same statistical tests were performed on the yields in the other study areas with the same results as in Wharton County.

Validating the crop yields is key to the reliability of any results that are simulated using the data. Validation of the energy prices in the ethanol model is necessary to produce reliable results indicating the probability of profit for an ethanol plant in Texas that uses sweet sorghum. Validation results for stochastic variables in the ethanol model are presented in the next section.

Validation of the Ethanol Model Stochastic Variables

Stochastic input and output prices are variables that must be validated in the ethanol model. Validation results for corn, ethanol, gasoline, natural gasoline, electricity, and WDGS prices are presented in this section.

Corn prices over the ten year horizon were validated against the forecasted mean FAPRI prices for each year in the study. Each t-test and Chi-Square test failed to reject that the simulated corn prices were significantly different from the forecasted price. Corn price validation results for 2008 and 2017 are found in Table 32. Results for 2009 through 2016 are found in Appendix A.

Trends in historical ethanol, gasoline, natural gas, and electricity prices were removed and the deviations from the trends were used to determine the stochastic prices for 2008-2017. The stochastic energy prices were compared to the historical residual means to test the mean and standard deviation (Table 33). All tests failed to reject that the mean and standard deviation for the stochastic and historical prices were significantly different at a 95% confidence level.

The stochastic mean WDGS prices were validated against the forecasted WDGS price based on the results from the regression between the forecasted corn and soybean meal price each year, and the Portales, NM WDGS selling price (Table 34). A Chi-Square test was not performed because the only historical WDGS price data available is for 2007 by the single bioenergy plant in New Mexico. The validation results validated the stochastic WDGS mean price.

All stochastic values with at least one year of historical or simulated data were validated to insure the reliability of the farm model and ethanol model output. Each of the t-tests and Chi-Square tests for yields, as well as input and output price variables, were statistically equal to their respective historical values. The results from the farm model and ethanol model rely heavily on the accuracy of the stochastic variables. The KOVs and results for each model are presented in Chapters VI and VII.

Table 32. Corn Price Validation Results for 2008 and 2017

Test of Hypothesis for Parameters for Corn Price 2008					
Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.65	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.66	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*
Test of Hypothesis for Parameters for Corn Price 2017					
Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.74	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.87	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*

Table 33. Validation Results for Ethanol, Gasoline, Natural Gas, and Electricity Stochastic Prices

Test of Hypothesis for Parameters for Ethanol Price

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	2.45	0.16	2.25	0.87	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.20	510.38	LB: 439.00	0.71	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*
			UB: 562.79		

Test of Hypothesis for Parameters for Gasoline Price

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	2.042650338	0.04	2.25	0.97	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.237832693	451.93	LB: 439.00	0.13	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*
			UB: 562.79		

Table 33. Continued

Test of Hypothesis for Parameters for Natural Gas Price

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	6.77	-0.12	2.25	0.91	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.81	485.57	LB: 439.00	0.68	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*
			UB: 562.79		

Test of Hypothesis for Parameters for Electricity Price

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	0.07	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal to the Given Value*
Chi-Square Test	0.00	488.46	LB: 439.00	0.75	*Fail to Reject the Ho that the Standard Deviation is Equal to the Given Value*
			UB: 562.79		

Table 34. Validation Results for Wet Distillers Grains with Solubles (WDGS) Prices

Test of Hypothesis for Parameters for WDGS					
Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	149.64	0.13	2.25	0.90	*Fail to Reject the Ho that the Mean is Equal to the Given Value*

CHAPTER VI

FARM MODEL RESULTS

The KOV from the farm model will be used in the ethanol model. The minimum sweet sorghum price that a risk averse farmer will accept to produce sweet sorghum over a traditional crop is an important variable in analyzing the economic feasibility of producing ethanol from sweet sorghum juice in Texas. The results from analyzing the four farm models are presented in this chapter.

Minimum Sweet Sorghum Price

The farm model simulated the net returns of traditionally grown crops and the total cost to produce sweet sorghum in each study area. The maximum of either the expected production cost of sweet sorghum plus 10% or the expected profit from the most profitable crop in the region represented the minimum sweet sorghum price offered to sweet sorghum farmers by the ethanol plant. The sweet sorghum price varied greatly across the four study areas. SERF was used for each study area to insure that risk averse producers would prefer to grow sweet sorghum at the fixed contract price rather than the most profitable crop presently grown in the region. Results for the net returns and minimum sweet sorghum prices are presented here for the four study areas.

Willacy County

The net returns for cotton, grain sorghum, and sweet sorghum in Willacy County were analyzed. The average net returns for crops in Willacy County ranged from $-142 to $325 per acre. Grain sorghum is the most profitable historical crop and has mean net returns of $325 per acre. The sweet sorghum contract price would have to be $11.44 per wet ton for it to be preferred over grain sorghum. Figure 5 shows the cumulative distribution function (CDF) of net returns for cotton, grain sorghum, and sweet sorghum in Willacy County. The most profitable crop (grain sorghum) is represented by the CDF farthest to the right while the least profitable crop is farthest to the left (cotton). Figure 5 indicates that sweet sorghum net returns are always greater than cotton net returns and greater than grain sorghum net returns over 50% of the time at $11.44 per wet ton. The CDF for sweet sorghum net returns is vertical, indicating that there is no variation in the net returns realized by a sweet sorghum producer in Willacy County because net returns are based on the average yield per acre and fixed price. This is different from the traditional crops because they rely on a variable market price to determine receipts and therefore experience price risk. Risk averse farmers prefer to reduce the risk they face by taking a guaranteed price for sweet sorghum (assuming the fixed price covers the production costs of sweet sorghum) rather than growing a crop with a moving market price. The SERF analysis shows that at a price of $11.44 per wet ton of sweet sorghum, farmers would be willing to grow sweet sorghum instead of grain sorghum Figure 6.

The preference of farmers to accept a fixed contract price for sweet sorghum that may be less than the possible net returns of traditional crops is reflected in the SERF

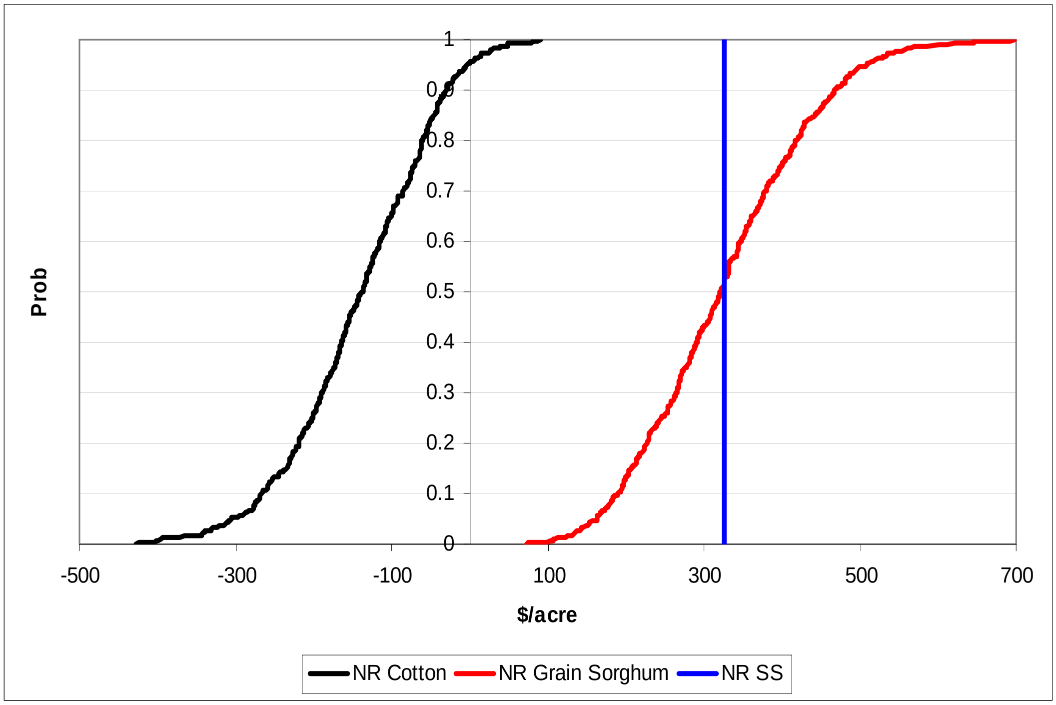


Figure 5. Cumulative Distribution Function of Crop Returns per Acre in Willacy County

analysis. The crop that ranks highest (the top line in the SERF chart) is preferred at each average risk aversion coefficient. For instance, a risk neutral farmer (farthest to the left) would be indifferent between growing sweet sorghum and grain sorghum, but would prefer to grow sweet sorghum instead of cotton. A normal risk averse farmer would prefer to grow sweet sorghum over grain sorghum and cotton. The preference of sweet sorghum compared to the traditional crops is the same for very risk averse individuals on the far right side of the SERF chart Figure 6.

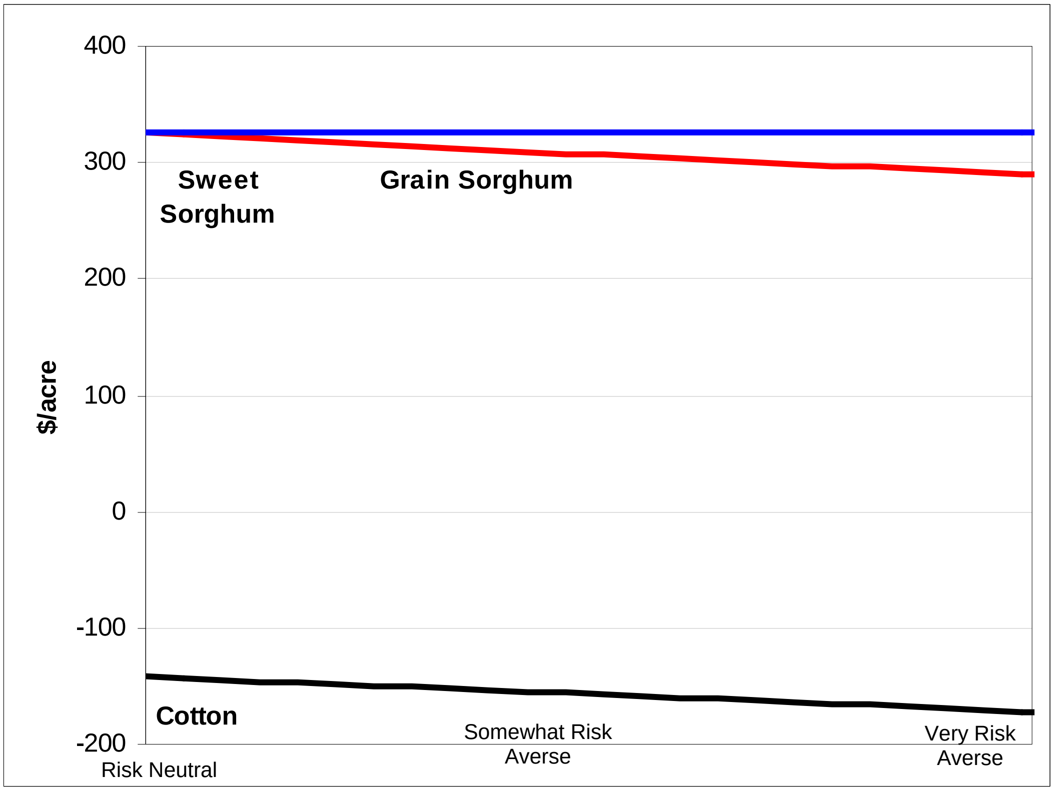


Figure 6. Stochastic Efficiency with Respect to a Function Results for Crop Returns per Acre in Willacy County

Wharton County

Rice and sweet sorghum net returns were compared in Wharton County. Rice is risky to grow, which is reflected by the wide range of possible net returns in the CDF in Figure 7. At a contract price of $9.94 per wet ton, SERF results indicate that a farmer at any given risk aversion level would be willing or prefer to grow sweet sorghum instead of rice (Figure 8).

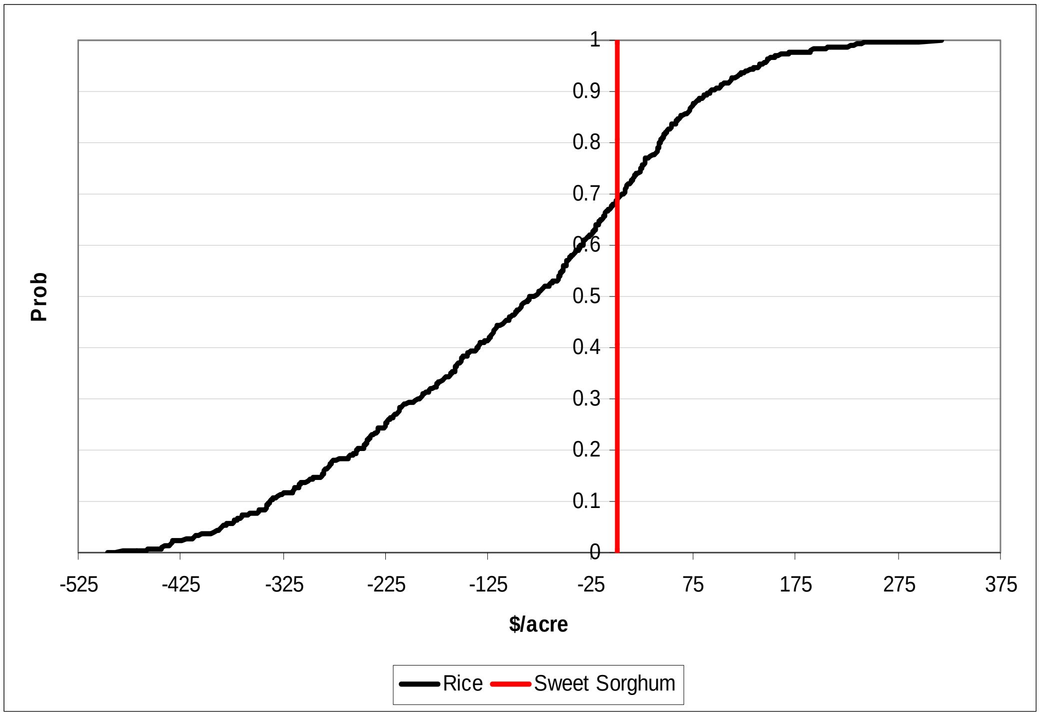


Figure 7. Cumulative Distribution Function of Crop Returns per Acre in Wharton County

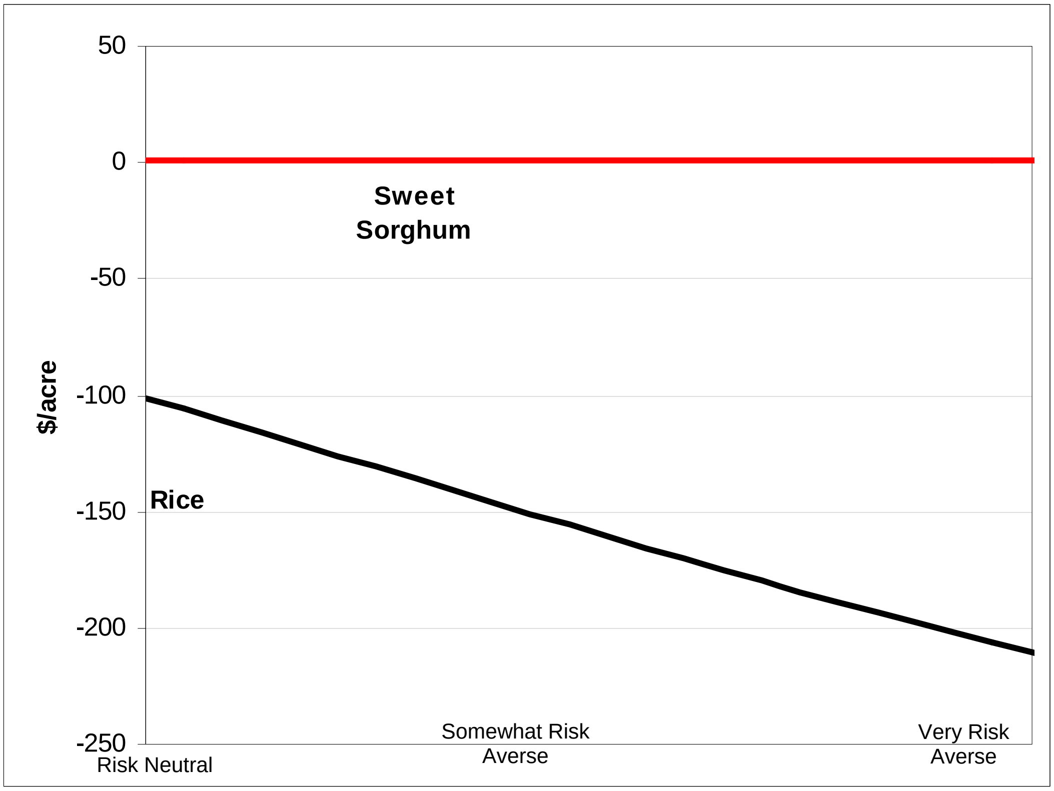


Figure 8. Stochastic Efficiency with Respect to a Function Results for Crop Returns per Acre in Wharton County

Hill County

Corn, grain sorghum, wheat, and sweet sorghum were included in the farm model. The CDFs for Hill County indicate that grain sorghum has the greatest possible profit; however, it also has the greatest amount of variability compared to wheat and corn (Figure 9). Grain sorghum has the greatest average net returns at $479 per acre. Average net returns for corn and wheat are lower at $280 and $124 per acre, respectively. Sweet sorghum would have an average net return of $479 per acre at $36.21 per wet ton. SERF analysis indicates that farmers would prefer to grow sweet sorghum over the other crops modeled in Hill County at a fixed price of $36.21 per wet ton (Figure 10).

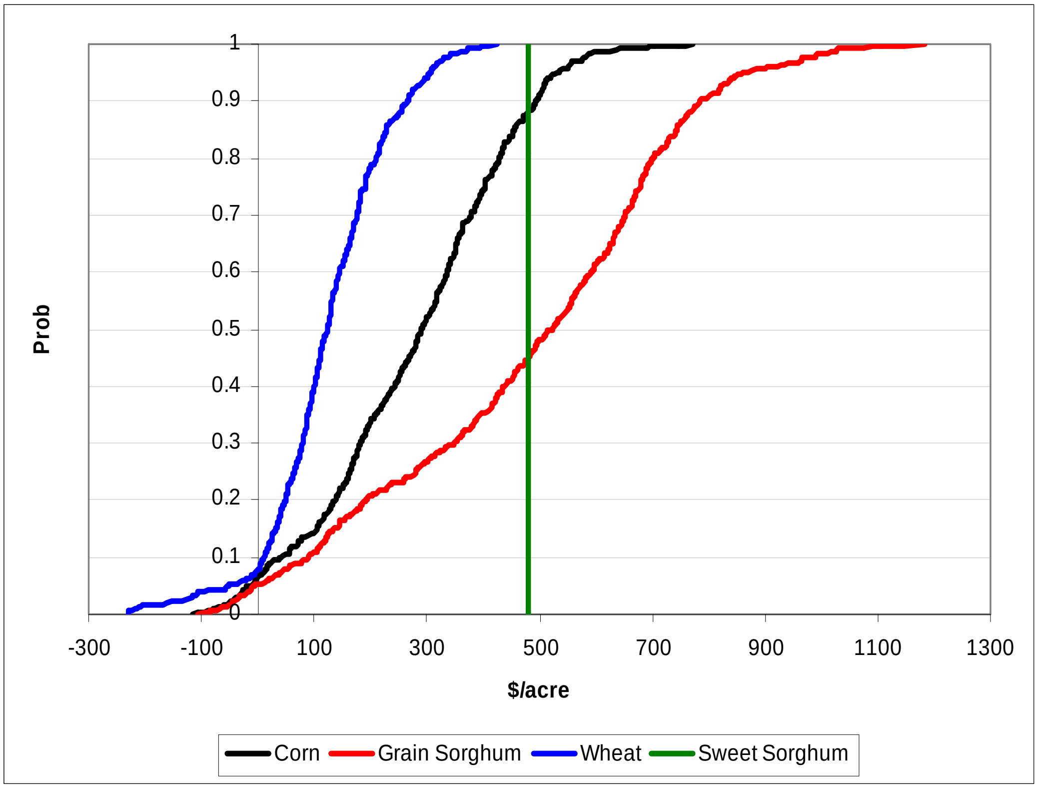


Figure 9. Cumulative Distribution Function of Crop Returns per Acre in Hill County

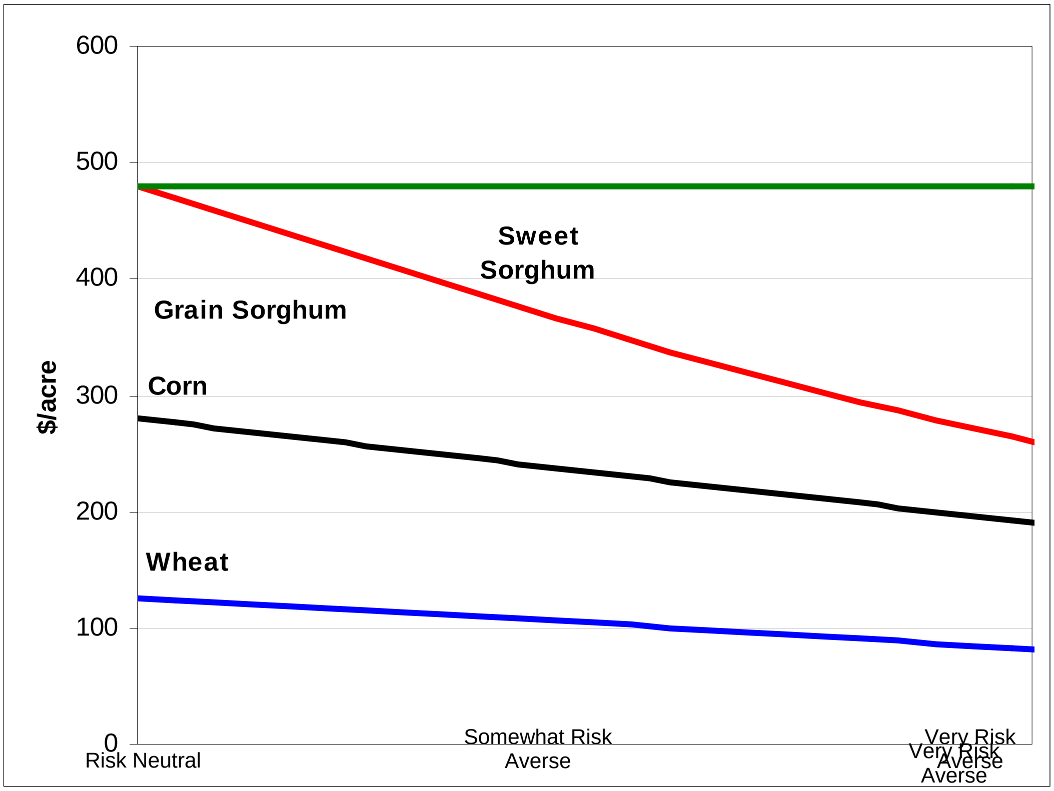


Figure 10. Stochastic Efficiency with Respect to a Function Results for Crop Returns per Acre in Hill County

Moore County

Corn, grain sorghum, wheat, and sweet sorghum were modeled in Moore County. The sweet sorghum price would have to be at least $28.98 per wet ton to yield net returns equal to higher than corn, the next most profitable crop in Moore County (Figure 11). Average net returns for corn, grain sorghum, wheat, and sweet sorghum were $407, $111, $105, and $407 per acre, respectively. Figure 12 shows the SERF results graph, which indicates that sweet sorghum and corn are equally desirable for risk neutral farmers but sweet sorghum is preferred at all other risk aversion levels.

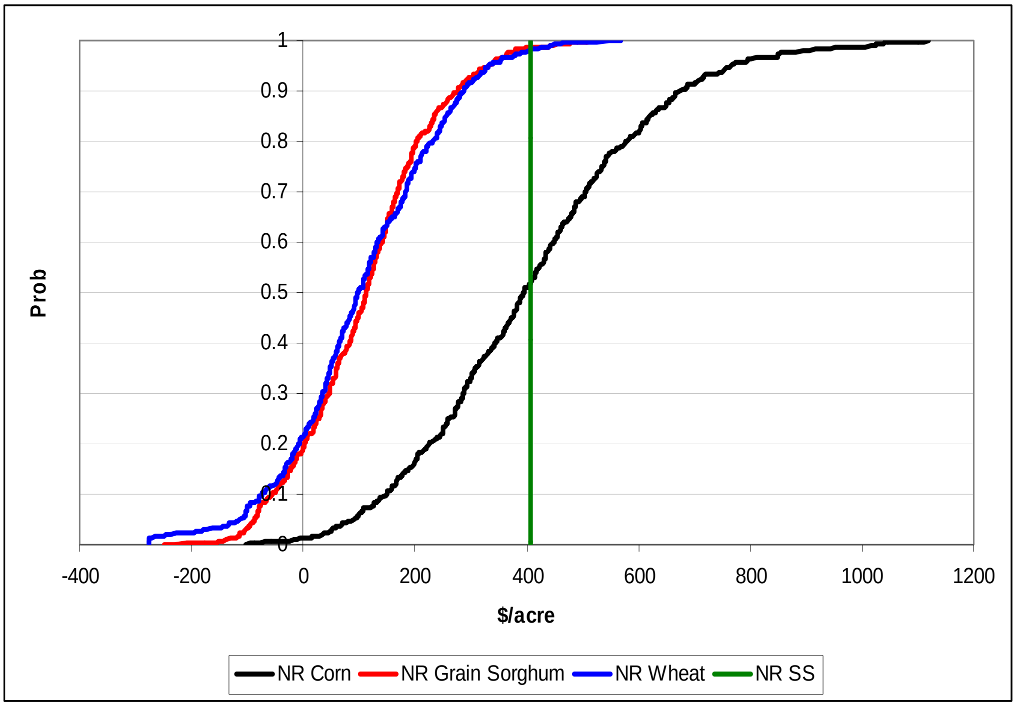


Figure 11. Cumulative Distribution Function of Crop Returns per Acre in Moore County

The minimum sweet sorghum price that a rational farmer would accept to grow sweet sorghum rather than the most profitable traditional crop in the study area varies across the four Texas areas (Table 35). Wharton County has the lowest minimum sweet sorghum price ($9.94) due to the losses incurred by rice on average. High yields and variability in grain sorghum net returns allow ethanol plants in Willacy County to pay the next lowest contract price ($11.44). Moore County farmers would require a substantially higher price per ton ($28.98) of sweet sorghum due to the profitability of corn in the area and the lower yields of sweet sorghum associated with a shorter growing season and less moisture. Low annual sweet sorghum yields and high grain sorghum

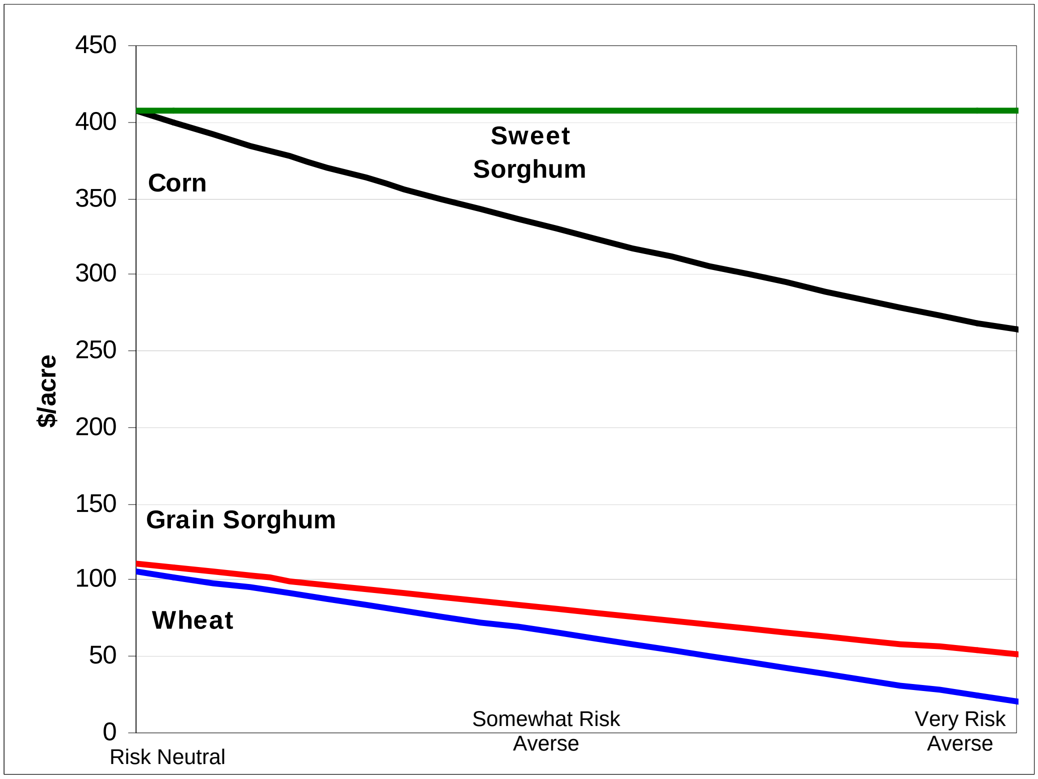


Figure 12. Stochastic Efficiency with Respect to a Function Results for Crop Returns per Acre in Moore County

Table 35. Sweet Sorghum Contract Price for Each Study Area

County	$/Wet Ton	$/Dry Ton
Willacy	11.44	14.87
Wharton	9.94	12.93
Hill	36.21	47.08
Moore	28.98	37.67

profits in Hill County will lead with the highest price ($36.21) paid for sweet sorghum out of the four study areas. The ethanol plant costs will be directly impacted by the minimum sweet sorghum price that farmers will be paid in each county.

The farm model KOVs are crucial input variables for simulating the economic feasibility of ethanol production from sweet sorghum juice in Texas. The minimum sweet sorghum price paid to farmers by the ethanol plant and the total number of contract acres required for full capacity ethanol production together will amount to an expense that cannot be easily altered without further technological advances in ethanol processing or feedstock characteristics that would increase ethanol production. The ethanol model results are presented in the Chapter VII.

CHAPTER VII

ETHANOL MODEL RESULTS

Results from simulating the ethanol model for both sweet sorghum only and sweet sorghum and corn in each study area, for the ten year planning period, are summarized in this chapter. Net present value and ending cash are used as indicators of the probability of success when sweet sorghum juice is used to produce ethanol in Texas. For ease of explanation, the two alternatives will be referred to as SS only and SS and corn for producing ethanol with only sweet sorghum versus sweet sorghum and corn, respectively.

Average Annual Ending Cash

Annual ending cash is the difference between the total cash inflows and total cash outflows each year. Annual ending cash indicates whether or not the refinery is achieving positive net cash income and paying principle payments and income tax versus creating cash flow deficit loans. Businesses with negative or declining ending cash over time tend to perform poorly and yield low (or negative) profits.

The ending cash summary statistics for 2008-2010, 2012, and 2017 are presented in Table 36. The first year of operation for the ethanol refineries modeled had a wide range of average ending cash across regions. Average ending cash for all counties using SS and corn was positive in 2008, compared to the negative average ending cash for SS only in all counties except for Willacy County. Variability in average ending cash is

Table 36. Ending Cash Summary Statistics for 2008-2010, 2012, and 2017

	Willacy		Wharton		Hill		Moore	
	SS Only	SS & Corn	SS Only	SS & Corn	SS Only	SS & Corn	SS Only	SS & Corn
				(million dollars)				
Ending Cash Reserves: Year 1								
Mean	1.46	41.82	-12.71	39.67	-51.34	12.88	-38.42	54.71
StDev	10.35	13.62	5.97	12.59	7.62	13.65	6.83	15.79
Min	-34.27	-0.87	-27.76	6.22	-70.48	-17.93	-58.61	16.20
Max	28.99	86.12	6.45	80.87	-33.56	50.62	-22.58	98.40
Prob(EC<0)	42%	0%	98%	0%	100%	16%	100%	0%
Ending Cash Reserves: Year 2								
Mean	1.34	82.91	-27.33	77.34	-105.04	20.55	-78.09	107.35
StDev	14.88	20.03	8.73	18.29	10.63	20.14	9.50	23.43
Min	-41.80	25.85	-57.36	24.98	-133.94	-28.06	-106.82	42.84
Max	46.16	154.06	8.35	137.21	-76.49	82.53	-49.77	176.86
Prob(EC<0)	46%	0%	100%	0%	100%	15%	100%	0%
Ending Cash Reserves: Year 3								
Mean	-2.07	118.57	-45.04	109.57	-164.17	22.00	-121.37	153.56
StDev	18.48	25.20	11.46	23.19	13.96	25.43	11.90	29.24
Min	-62.46	30.18	-79.82	40.22	-204.95	-43.18	-155.20	70.29
Max	52.21	211.92	-2.93	205.13	-124.44	116.41	-84.76	272.20
Prob(EC<0)	54%	0%	100%	0%	100%	20%	100%	0%
Ending Cash Reserves: Year 5								
Mean	-7.49	192.05	-82.95	175.21	-294.38	25.40	-217.29	245.99
StDev	23.95	32.67	15.75	31.28	19.24	34.68	15.92	38.39
Min	-85.15	87.44	-130.32	90.81	-349.86	-59.57	-263.26	141.32
Max	60.86	310.65	-27.42	303.14	-238.75	171.04	-169.97	412.11
Prob(EC<0)	63%	0%	100%	0%	100%	25%	100%	0%
Ending Cash Reserves: Year 10								
Mean	-13.69	392.18	-198.74	352.73	-714.61	45.79	-529.48	490.93
StDev	40.79	49.28	26.76	45.41	33.49	53.62	28.98	58.15
Min	-133.80	218.18	-278.53	211.16	-812.93	-150.00	-627.65	302.75
Max	111.25	553.79	-120.38	516.70	-597.95	237.78	-436.52	697.06
Prob(EC<0)	61%	0%	100%	0%	100%	19%	100%	0%

Note: Sweet Sorghum (SS), Standard Deviation (StDev), Minimum (Min), Maximum (Max); Prob(EC<0) is the probability that ending cash is less than zero.

greater for SS and corn as indicated by the range between the minimum and maximum ending cash.

Average ending cash increases in all areas when corn is added to the production scheme (Table 36). Mean ending cash increases over time in the SS and corn alternative while mean ending cash becomes more negative in the SS only operating scenario over time. There is a smaller range of ending cash when using SS only because incorporating corn increases the firm’s risk, due to the feedstock price risk. The average ending cash in Willacy County is positive for the first year for both operating scenarios; however, average ending cash begins to decrease over the planning horizon for SS only compared to increasing average ending cash for SS and corn. The probability of negative ending cash increases in Willacy County for the SS only alternative. Moore County yields the highest ending cash each year because it utilizes more corn than sweet sorghum. Willacy, Wharton, and Moore Counties have a 100% chance of achieving positive ending cash under the SS and corn scenario, whereas Hill County has at least a 15% chance of experiencing negative ending cash in any given year. All study areas have decreasing ending cash reserves when operating under the dual feedstock alternative.

Net Present Value

Net present value is an indicator of success over a multi-year period, and as such, is appropriate to use for the ethanol model. Results for each study area and alternative are presented below.

The average NPV is very different for the eight alternatives (Table 37). The SS only average NPV ranges from -\$11.06 in Willacy County to -\$712.00 million in Hill County, while the SS and corn scenario range across the four study areas is \$492.39 in Moore County to \$48.40 in Hill County. An investment is considered an economic success when NPV is greater than zero because it indicates the rate of return is greater than the discount rate. The probability for economic success is 100% in Willacy, Wharton, and Moore Counties using SS and corn to produce ethanol. Hill County has a 82% probability of economic success for SS and corn. Willacy County is the only study area that has a chance at success using SS only, and even then, the probability of success is only 41%.

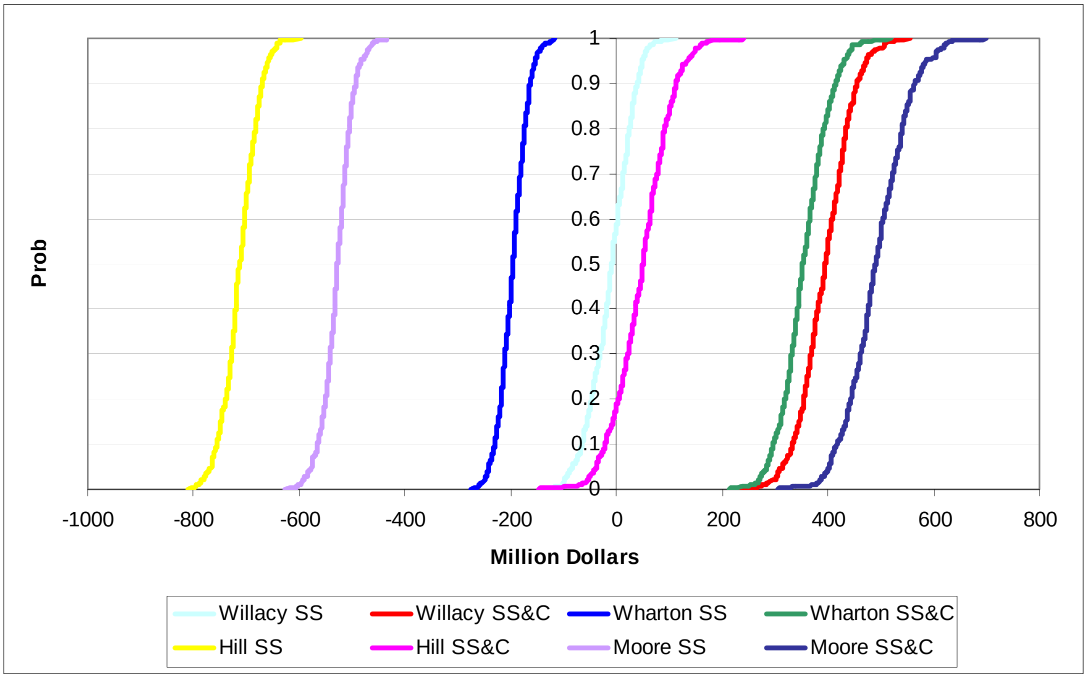
Table 37. Summary Statistics for Net Present Value in Each Study Area and Scenario

	Willacy		Wharton		Hill		Moore	
	SS Only	SS & Corn	SS Only	SS & Corn	SS Only	SS & Corn	SS Only	SS & Corn
				(million dollars)				
Mean	-11.06	394.81	-196.08	355.39	-712.00	48.40	-527.97	492.39
StDev	40.79	49.28	26.76	45.41	33.49	53.62	28.98	58.15
Min	-131.17	220.81	-275.87	213.82	-810.32	-147.39	-626.15	304.21
Max	113.87	556.41	-117.71	519.36	-595.34	240.39	-435.02	698.52
Prob(NPV>0)	41%	100%	0%	100%	0%	82%	0%	100%

Note: Sweet Sorghum (SS), Standard Deviation (StDev), Minimum (Min), Maximum (Max), Net Present Value (NPV); Prob(NPV>0) is the probability that net present value is greater than zero.

The output presented in Figure 13 is the cumulative distribution function (CDF) of NPVs based on a 500 iteration simulation of each ethanol plant and feedstock combination. The CDF shows the probability that NPV will be less than a particular value on the x-axis. Thus, a CDF which lies to the right of a second CDF is preferred because there is a smaller probability of having a lower NPV. In the event that CDF's cross, preference cannot be identified easily, and SERF can be used to determine the preference.

The CDF results in Figure 13 show the simulated NPV for each study area and alternative. The NPV distributions for an ethanol plant in Willacy County are positive for SS only (light blue line) with a 41% chance of being positive and a 100% probability of positive NPV for SS and corn (red line) (Figure 13).



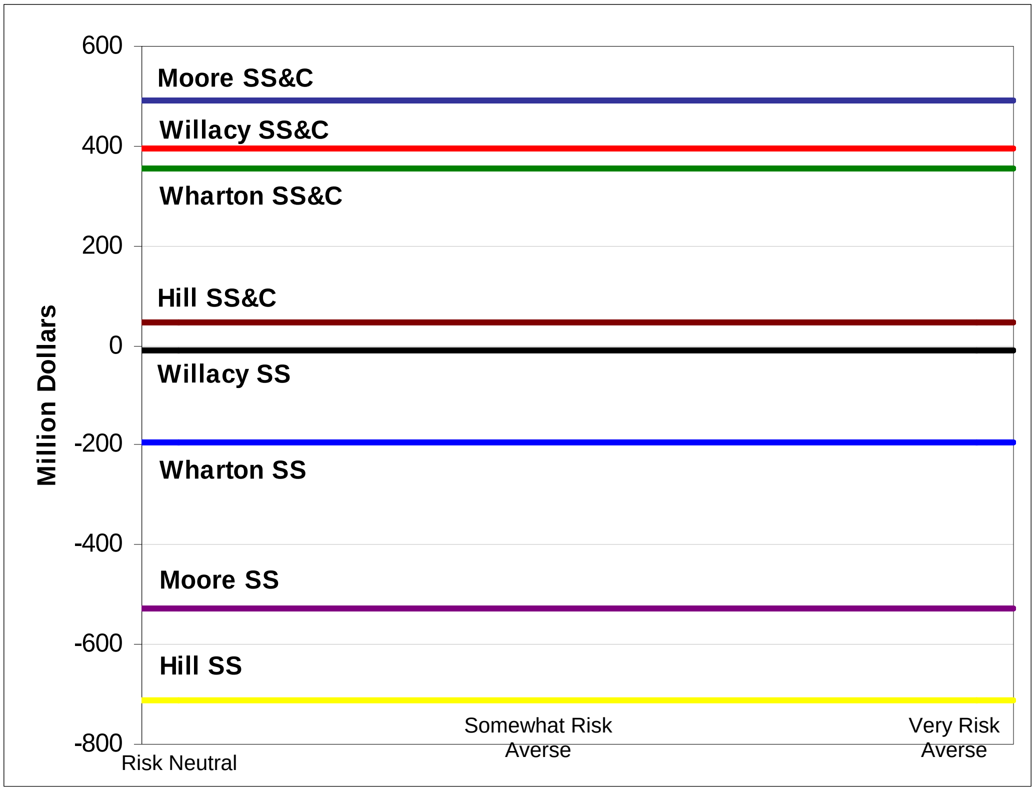
Note: Probability (Prob), Sweet Sorghum (SS), Sweet Sorghum and Corn (SS & C)

Figure 13. Cumulative Distribution Function of Net Present Value for Each Study Area and Alternative

Wharton County has a higher NPV distribution for SS and corn compared to using SS only. Using SS only causes the distribution to be negative in Wharton County. Hill County has a 20% probability of negative NPVs for SS and corn, and using SS only makes 100% of the NPVs negative. Moore County also has negative NPVs distributions when using SS only, but has a 100% probability of positive NPVs using both feedstocks. Additional analysis in Moore County using only corn would more than double the NPV compared to producing ethanol with SS and corn. All of the alternatives, with the exception of ethanol plants using SS and corn, are likely to have negative NPVs.

SERF was used to rank the NPV CDFs (Figure 14). All decision makers would prefer to operate in Moore County using SS and corn to produce ethanol. All risk averse decision makers would prefer the SS and corn feedstock to using SS only in the four study areas.

The simulation results are not surprising considering the assumptions for the different regions (Table 38). Because Moore County operates primarily with a storable feedstock that costs less per unit than sweet sorghum, production can occur throughout the year with little regard to seasonality. The other three study areas use more sweet sorghum and therefore are concerned with the sweet sorghum yields each year. Even in poor production years the ethanol plants pay the farmer the contract price for a pre-determined amount of sweet sorghum which leads to higher costs when corn has to be purchased to supplement ethanol production.



Note: Sweet Sorghum (SS), Sweet Sorghum and Corn (SS & C)

Figure 14. Stochastic Efficiency with Respect to a Function Analysis of Net Present Values for Each Study Area and Alternative

The number of harvests in an area, number of days sweet sorghum is used as a feedstock, annual yield of sweet sorghum per acre, number of contracted acres, and contracted sweet sorghum price per ton influence the results greatly. Of the three study areas that use significantly more sweet sorghum than Moore County (when using dual feedstocks), Willacy County was the most preferred alternative after largely because there is a 100 % chance of three sweet sorghum harvests compared to a 42 % chance in Wharton County and no chance of three harvests in Hill County. Multiple

Table 38. Assumptions that Explain Net Present Value Differences Across Areas

	Willacy	Wharton	Hill	Moore
Probability of One Cut	100%	100%	100%	100%
Probability of Two Cuts	100%	100%	75%	0%
Probability of Three Cuts	100%	18%	0%	0%
Average Number of Cuts	3	2	2	1
Average Number of Days Using Sweet Sorghum	198	136	102	36
Average Annual Sweet Sorghum Yield per Acre	137.32	47.08	33.06	23.70
Number of Contracted Acres	15,600	29,430	37,700	28,500
Sweet Sorghum Contract Price per Ton	11.44	9.94	36.21	36.68

Note: Net Present Value (NPV)

sweet sorghum harvests, coupled with high yields per acre, allow more tons of sweet sorghum to be harvested and thus a longer sweet sorghum ethanol production period. The additional harvest and hauling cost for the high tonnage of sweet sorghum in Willacy County is offset by the revenue gained through economies of scale in a Willacy County ethanol plant.

The results of the analysis indicate that ethanol production using SS and corn in Moore County is the most profitable and preferred because it is essentially a corn plant supplemented by sweet sorghum. The second best alternative for all risk averse decision makers is to produce ethanol in Willacy County using both feedstocks. Ethanol production in Wharton, Hill, and Moore Counties using SS only is uneconomical.

CHAPTER VIII

SUMMARY

Rising energy costs, instability in oil exporting countries, and concerns for the environment have created a great deal of interest in alternative fuels such as ethanol. As gasoline prices increase and more pressure is put on the government to invest in or encourage production of alternative fuels, more businesses, farmers, cooperatives, and investors are interested in the feasibility of producing ethanol.

Multiple studies have analyzed the feasibility of producing ethanol using corn and other feedstocks in an array of geographical locations. However, there are not currently any studies that use stochastic simulation to analyze the economic feasibility of producing ethanol from sweet sorghum juice in Texas, nor the potential profits for sweet sorghum farmers. The objective of this thesis is to fill that gap in the literature.

Stochastic variables were used in two models: one for the farm and another for the ethanol refinery. The farm model estimated the price an ethanol plant must pay farmers to produce sweet sorghum. The ethanol model estimated the PDFs for NPV to rank which operating alternative is most preferred. The analysis tested the feasibility of using only SS or SS with corn as feedstocks for the ethanol plant. Four counties were considered: Willacy, Wharton, Hill, and Moore.

The farm level results to calculate the minimum contract price for sweet sorghum varied greatly across the study areas. The sweet sorghum contract price ranged from $9.94 per ton in Wharton County to $36.21 per ton in Hill County with $11.44 and

$28.98 per ton being the minimum contract prices in Willacy and Hill Counties, respectively.

Moore County was the most profitable study area when using sweet sorghum and corn because it utilized corn a majority of the time. Willacy County was the next most profitable study area when using sweet sorghum and corn and out performed the other areas using sweet sorghum only. Hill County using sweet sorghum only was the least preferred alternative because of low annual sweet sorghum yields and high feedstock costs. An ethanol plant using sweet sorghum is economically successful in the Panhandle, the Coastal Bend, Central Texas (80% of the time), and the Valley if corn is used when sweet sorghum is unavailable. Only Willacy County had a possibility of yielding a positive net present value when using sweet sorghum only.

Further analysis is needed on the economic feasibility of using different feedstocks, such as grain sorghum, with sweet sorghum to produce ethanol. Grain sorghum yields the same number of gallons of alcohol per bushel as corn does, but is slightly cheaper per bushel, grows in a larger range of geographical locations, and requires fewer inputs than corn. Ethanol producers and stakeholders interested in new technology such as incorporating sweet sorghum into the cellulosic conversion process will benefit from further economic feasibility analysis. The community economic impacts of buying all feedstock locally has not been analyzed extensively and is another area of possible research.

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APPENDIX A

Appendix Table 1. Simulated CroPMan Yields for 1960-2006a for Selected Crops in Willacy and Wharton Counties

	Willacy			Wharton	
Year	IR Cotton	IR Grain Sorghum	Sweet Sorghum	Rice	Sweet Sorghum
	lb/acre	cwt/acre	ton/acre	cwt/acre	ton/acre
1960	1,269	42	23	87	34
1961	1,251	44	28	94	34
1962	1,383	45	25	82	33
1963	1,210	42	26	79	31
1964	1,350	53	26	85	33
1965	1,236	47	24	82	31
1966	1,090	37	23	88	31
1967	1,269	51	33	84	36
1968	1,286	46	24	86	30
1969	1,201	41	24	79	22
1970	1,246	52	24	84	27
1971	1,245	44	25	84	33
1972	1,454	54	28	92	31
1973	1,192	40	23	84	29
1974	1,200	41	28	91	32
1975	1,322	50	26	86	28
1976	1,314	45	22	85	26
1977	1,271	43	25	78	28
1978	1,242	44	26	85	28
1979	1,368	52	26	90	18
1980	1,214	50	28	89	33
1981	1,232	48	23	84	26
1982	1,166	48	22	82	31
1983	1,170	45	23	88	28
1984	1,152	49	27	86	31
1985	1,217	51	28	98	35
1986	1,293	51	29	83	22
1987	1,142	41	22	85	26
1988	1,211	44	22	86	30
1989	1,060	38	26	82	28
1990	1,091	38	20	83	24
1991	1,171	48	32	84	29

Appendix Table 1. Continued

	Willacy			Wharton	
Year	IR Cotton	IR Grain Sorghum	Sweet Sorghum	Rice	Sweet Sorghum
	lb/acre	cwt/acre	ton/acre	cwt/acre	ton/acre
1992	1,224	42	25	78	23
1993	1,276	50	25	82	22
1995	1,294	53	25	91	27
1996	1,176	43	25	87	27
1997	976	38	25	79	27
1998	1,009	35	25	86	26
1999	1,143	52	25	85	26
2000	1,337	53	25	91	25
2001	1,244	43	25	80	31
2002	1,124	44	25	75	36
2003	1,205	40	25	64	37
2004	1,225	44	25	80	25
2005	1,089	42	25	72	26
2006	1,067	47	25	84	36

Note: Irrigated (IR), Pound (lb), Hundred Weight (cwt)
Source[a]: CroPMan®, Wyatte Harman, 2007

Appendix Table 2. Simulated CroPMan Yields for 1960-2006a for Selected Crops in Hill and Moore Counties

	Hill				Moore			
Year	DL Corn	DL Grain Sorghum	DL Wheat	Sweet Sorghum	IR Corn	IR Grain Sorghum	IR Wheat	Sweet Sorghum
	bu/acre	cwt/acre	bu/acre	tons/acre	bu/acre	cwt/acre	bu/acre	tons/ac
1960	150	50	-	25	238	77	-	28
1961	157	60	54	30	230	77	66	23
1962	142	41	62	24	213	76	32	28
1963	121	40	40	19	176	65	30	28
1964	72	25	54	20	189	64	90	25
1965	126	44	43	19	240	76	86	26
1966	139	52	63	22	191	63	28	21
1967	104	25	14	30	231	75	44	20
1968	150	55	39	20	215	74	92	25
1969	92	26	44	17	214	68	51	25
1970	48	22	53	20	210	74	47	25
1971	113	25	36	26	197	73	45	26
1972	115	30	51	20	243	76	74	25
1973	145	56	47	20	217	75	80	24
1974	77	12	44	26	170	70	27	26
1975	148	49	58	18	235	76	62	22
1976	150	54	45	22	210	67	63	22
1977	87	36	36	18	180	69	81	27
1978	54	15	44	19	197	68	65	25
1979	151	47	49	18	198	71	87	23
1980	94	18	48	16	180	63	95	25
1981	142	54	50	19	193	71	85	28
1982	151	49	45	18	221	69	50	22
1983	126	48	47	22	172	55	57	19
1984	96	20	49	19	209	70	94	23
1985	132	50	40	19	211	72	74	23
1986	149	48	41	22	227	68	57	24
1987	148	47	30	24	230	70	61	26
1988	96	35	40	18	226	70	88	24
1989	143	57	42	19	245	75	82	21
1990	107	35	28	17	229	81	61	28
1991	102	43	34	21	242	73	39	19
1992	144	50	38	17	224	76	102	20
1993	107	48	32	19	217	68	107	17

Appendix Table 2. Continued

	Hill				Moore			
Year	DL Corn bu/acre	DL Grain Sorghum cwt/acre	DL Wheat bu/acre	Sweet Sorghum ton/acre	IR Corn bu/acre	IR Grain Sorghum cwt/acre	IR Wheat bu/acre	Sweet Sorghum ton/acre
1996	71	16	33	24	194	77	69	27
1997	153	48	32	17	214	69	76	19
1998	98	37	31	17	202	72	75	28
1999	117	53	37	18	233	72	62	23
2000	137	52	42	18	221	64	96	24
2001	103	48	33	19	197	62	55	25
2002	121	50	31	19	216	75	49	28
2003	114	47	38	21	193	57	61	24
2004	123	56	36	20	233	70	97	25
2005	98	36	39	19	221	71	54	21
2006	56	25	26	20	172	65	46	26

Note: Dryland (DL), Irrigated (IR) Bushel (bu), Hundred Weight (cwt)
Source[a]: CroPMan®, Wyatte Harman, 2007

Appendix Table 3. Itemized Costs in the 2008 Budget for a Sweet Sorghum Farm in Willacy County

	IR Cotton (lb)[a]	IR Grain Sorghum(cwt)[a]	Sweet Sorghum (ton)[b]
		$/acre	
Variable Costs			
Seed	65.82	6.54	11.67
Fertilizer	66.73	69.69	55.60
Herbicides	32.87	19.88	7.79
Insecticides	37.34	-	-
Irrigation	45.00	16.25	100.00
Other Production	43.22	-	-
Drying, Hauling, etc.	282.15	21.64	-
Crop Insurance Premiums	11.25	-	-
Main Crop Variable Cost	584.38	133.99	175.06
Total Variable Costs	584.38	133.99	175.06
Overhead Costs			
Cash Rent	103.70	58.48	80.00
Labor	54.93	21.45	54.14
Maintenance and Repairs	22.23	8.68	-
Accounting & Legal	0.87	0.34	-
Fuel & Lube	32.35	22.00	48.10
Utilities	3.63	1.42	1.42
Insurance	7.71	3.01	3.01
Miscellaneous	1.18	0.46	0.46
Fraction of Year Interest Paid	0.33	0.33	0.33
Operating Interest Rate	8%	8%	8%
Depreciation	16.35	16.35	16.35
Total Overhead Costs	226.59	115.84	187.14

Note: Irrigated (IR), Pound (lb), Hundred Weight (cwt)

Source[a]: Herbst et al., 2007

Source[b]: TAR, 2007

Appendix Table 4. Itemized Costs in the 2008 Budget for a Sweet Sorghum Farm in Hill County

	DL Corn (bu)[a]	DL Cotton (lb)[a]	DL Grain Sorghum (cwt)[a]	DL Wheat (bu)[a]	Sweet Sorghum (ton)[b]
			$/acre		
Variable Costs					
Seed	30.43	67.17	9.97	16.83	11.67
Fertilizer	78.47	51.39	68.02	53.31	117.71
Herbicides	19.56	57.60	24.73	4.35	1.19
Insecticides	3.52	49.60	9.06	14.77	-
Irrigation	-	-	-	-	-
Other Production	-	50.25	5.30	5.30	-
Drying, Hauling, etc.	28.34	120.39	30.87	25.13	-
Crop Insurance Premiums	4.02	5.55	3.84	2.62	-
Main Crop Variable Cost	164.34	401.95	151.79	122.32	130.57
Total Variable Costs	164.34	401.95	151.79	122.32	130.57
Overhead Costs					
Cash Rent	63.73	56.70	61.87	43.65	65.00
Labor	20.55	28.04	19.98	14.76	-
Maintenance and Repairs	11.82	16.13	11.49	8.49	-
Accounting & Legal	0.57	0.77	0.55	0.41	-
Fuel & Lube	23.67	32.29	20.54	15.18	10.51
Utilities	5.61	7.65	5.45	4.03	-
Insurance	2.88	3.93	2.80	2.07	-
Miscellaneous	0.57	0.78	0.56	0.41	-
Fraction of Year Interest Paid	0.15	0.15	0.15	0.15	0.15
Operating Interest Rate	9%	9%	9%	9%	9%
Depreciation	15.60	15.60	15.60	15.60	15.60
Total Overhead Costs	129.40	146.29	123.24	89.00	75.51

Note: Dryland (DL), Bushel (bu), Pound (lb), Hundred Weight (cwt)
Source[a]: Herbst et al. 2007
Source[b]: TAR, 2007

Appendix Table 5. Itemized Costs in the 2008 Budget for a Sweet Sorghum Farm in Moore County

	IR Corn (bu)[a]	IR Grain Sorghum (cwt)[a]	IR Wheat (bu)[a]	Sweet Sorghum (ton)[b]
	$/acre			
Variable Costs				
Seed	59.14	-	24.93	11.67
Fertilizer	149.85	105.81	29.64	90.00
Herbicides	38.04	40.48	4.35	1.19
Insecticides	10.67	16.00	6.67	-
Irrigation	296.84	212.03	106.01	192.95
Other Production	28.14	20.89	20.44	7.49
Drying, Hauling, etc.	2.73	-	0.76	-
Crop Insurance Premiums	6.55	4.64	3.70	-
Main Crop Variable Cost	591.95	399.85	196.50	303.30
Total Variable Costs	591.95	399.85	196.50	303.30
Overhead Costs				
Cash Rent	93.01	117.23	23.23	75.00
Labor	28.99	28.73	9.03	-
Maintenance and Repairs	42.35	41.97	13.20	-
Accounting & Legal	2.83	2.80	0.88	-
Fuel & Lube	22.69	22.49	7.08	53.84
Utilities	6.40	6.34	1.99	-
Insurance	2.92	2.89	0.91	-
Miscellaneous	0.96	0.95	0.30	-
Fraction of Year Interest Paid	0.60	0.60	0.60	0.60
Operating Interest Rate	0.08	0.08	0.08	0.08
Depreciation	10.37	10.37	10.37	10.37
Total Overhead Costs	200.15	223.40	56.62	128.84

Note: Irrigated (IR), Bushel (bu), Hundred Weight (cwt)

Source[a]: Herbst et al. 2007

Source[b]: TAR, 2007

Appendix Table 6. Crop Budget Summary in Each Study Area

	Corn (bu)	Cotton (lb)	Rice (cwt)	Grain Sorghum (cwt)	Wheat (bu)	Sweet Sorghum (ton)
Average Market Price	6.42	0.51	8.33	9.25	8.59	-
Willacy County						
Average Yield	-	1,000.00	-	69.00	-	62.42
Total Returns	-	688.66	-	574.47	-	-
Variable Cost	-	584.38	-	133.99	-	175.06
Fixed Cost	-	226.59	-	115.84	-	187.14
Total Cost	-	810.97	-	249.83	-	362.20
Expected Net Return per Acre	-	(142.26)	-	325.51	-	325.51
Contract price						11.44
Wharton County						
Average Yield	-	-	82.73	-	-	28.00
Total Returns	-	-	764.91	-	-	-
Variable Cost	-	-	658.29	-	-	154.90
Fixed Cost	-	-	381.94	-	-	87.16
Total Cost	-	-	1,040.24	-	-	242.06
Expected Net Return per Acre	-	-	(101.02)	-	-	295.72
Contract price						9.94
Hill County						
Average Yield	100.92	507.10	-	89.32	42.18	20.21
Total Returns	647.65	316.21	-	743.65	362.42	-
Variable Cost	164.34	401.95	-	151.79	122.32	130.57
Fixed Cost	129.40	146.29	-	123.24	89.00	75.51
Total Cost	293.74	548.24	-	275.03	211.32	206.08
Expected Net Return per Acre	280.20	479.38	-	479.38	124.96	479.38
Contract price						36.21

Appendix Table 6. Continued

	Corn (bu)	Cotton (lb)	Rice (cwt)	Grain Sorghum (cwt)	Wheat (bu)	Sweet Sorghum (ton)
Moore County						
Average Yield	211.93	-	-	89.32	45.19	30.00
Total Returns	1,360.05	-	-	743.65	388.28	-
Variable Cost	591.95	-	-	399.85	196.50	303.30
Fixed Cost	200.15	-	-	223.40	56.62	128.84
Total Cost	792.10	-	-	623.25	253.13	432.14
Expected Net Return per Acre	407.22	-	-	111.46	105.83	407.22
Contract price						28.98

Appendix Table 7. Corn Price Validation Results for 2009-2016

Test of Hypothesis for Parameters for Corn Price 2009

	Given Value	Test Value	Critical Value	P-Value	
Confidence Level		95.0000%			
t-Test	4.67	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.70	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Test of Hypothesis for Parameters for Corn Price 2010

	Given Value	Test Value	Critical Value	P-Value	
Confidence Level		95.0000%			
t-Test	4.59	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.75	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Test of Hypothesis for Parameters for Corn Price 2011

	Given Value	Test Value	Critical Value	P-Value	
Confidence Level		95.0000%			
t-Test	4.70	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.75	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Appendix Table 7. Continued

Test of Hypothesis for Parameters for Corn Price 2012

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.63	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.74	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Test of Hypothesis for Parameters for Corn Price 2013

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.68	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.78	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Test of Hypothesis for Parameters for Corn Price 2014

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.72	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.84	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Appendix Table 7. Continued

Test of Hypothesis for Parameters for Corn Price 2015

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.73	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.76	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

Test of Hypothesis for Parameters for Corn Price 2016

Confidence Level		95.0000%			
	Given Value	Test Value	Critical Value	P-Value	
t-Test	4.72	0.00	2.25	1.00	*Fail to Reject the Ho that the Mean is Equal*
Chi-Square Test	0.82	500.00	LB: 439.00 UB: 562.79	0.96	*Fail to Reject the Ho that the Standard Deviation is Equal*

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