A Case Study of the Impact of Bioenergy Development Upon

Crop Production, Livestock Feeding, and Water Resource Usage

in Kansas

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A Case Study of the Impact of Bioenergy Development Upon Crop Production, Livestock Feeding, and Water Resource Usage in Kansas

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The purpose of this article is to provide an analysis of the impact of ethanol development on various aspects of Kansas agriculture. This case study is relevant because it attempts to analyze the economic impact of Kansas bioenergy development on sectors of the state's agricultural economy that have broader implications and impacts for U.S. domestic and world grain and livestock markets. Research on this project has been underway since June 2007, utilizing internal grant funding from K-State Research and Extension. Final completion for this multi-faceted project is targeted for September 2008.

Expansion of ethanol production in Kansas in recent years has greatly increased the total quantity of feedgrain usage by the bioenergy industry in the state. Ten (10) ethanol plants are now in production with projected total capacity to produce 322 million gallons of ethanol annually. Although crop producers are experiencing the benefits of higher grain prices which are at least partially due to bioenergy-related demand for grain, Kansas livestock feeders have experienced the adverse effects of historically high feedgrain prices, resulting in tighter profit margins. For Kansas livestock feeding operations to remain profitable and sustainable over time, they will be forced to compete for feedgrain supplies with the growing number of Kansas ethanol plants, although ethanol plants do produce distiller's grains which add to the supply of available feed ration options.

Western Kansas livestock feeders and ethanol producers throughout the state have been supplementing Kansas-grown feedgrains with imported supplies (primarily corn) transported by truck or rail, typically from Nebraska or Iowa. In 2007 the total amount of corn and grain sorghum needed to operate the 10 existing Kansas ethanol plants at full capacity was approximately 119 million bushels, equaling 21% of average total Kansas corn and grain sorghum production during the 2005-2007 period. Use of feedgrains in livestock rations in Kansas during this same period is estimated to average 158 million bushels per year (Appendix B, Table 2). With continued expansion in bioenergy production, Kansas may be experiencing a relative feedgrain supply shortage at present, and would be expected to experience more serious in-state supply shortages in times of drought-shortened feedgrain production. Agricultural Economists in Nebraska and Iowa have projected that their respective states will become grain deficit within a short time due to rapid expansion in grain-based ethanol production, and would then be unable to transport feedgrains to help supply the Kansas livestock and/or ethanol industries.

It is well established that water tables in Western Kansas in the Ogallala Aquifer have declined since intensive irrigation development began in the 1960s. As demand for

Kansas feedgrains continues to increase due to growth in grain-based ethanol processing, usage of irrigation water to produce feedgrains in Western Kansas is also likely to increase, straining and further accelerating the decline in available groundwater supplies in the Ogallala Aquifer. Water supply sustainability issues in Western Kansas extend beyond cropland irrigation, including the adequacy of water supplies for livestock feeding, bioenergy processing, communities, and other industrial uses.

As a result of the increased demand for feedgrains associated with Kansas bioenergy development, the acreage of water-intensive, fully irrigated corn will likely increase at the expense of alternative, less intensively irrigated crop enterprises (limited irrigation corn, grain sorghum, soybeans, sunflowers, wheat, etc.). Non-irrigated crop acreage is also likely to shift toward greater feedgrain production.

The infrastructure of the Kansas grain handling and transportation industry has also been affected by bioenergy development. The grain storage and handling role of local grain elevators has been impacted by changes in the directional flow of feedgrains which have occurred to supply feedstocks for ethanol plants. New livestock feed markets and transportation logistical opportunities have emerged as ethanol co-products distillers grains have gained acceptance by livestock feeders in their feed rations.

This article will begin with a discussion of the impact ethanol production has had on water use in Kansas, followed by an analysis of ethanol-related impacts upon Kansas crop and livestock industries. The effects of weather factors on nonirrigated corn production in Kansas will provide insight on how corn yield risk and uncertainty may affect the state's ability to meet its feedgrain needs. This section is followed by an analysis of the truck and rail transportation needs of a representative Kansas ethanol plant, with a discussion of the application of these transportation findings on a statewide basis. Finally, plans for a survey of Kansas grain elevators are presented, focusing on the scope and subject matter to be addressed.

Ethanol Production and Water Usage

For most of the Corn Belt, water consumption to produce ethanol is not an issue. Groundwater and annual rainfall provides enough water for grain and ethanol production. However, in the extreme western part of the Corn Belt, such as in Western Kansas, water was a major issue even before ethanol production expansion. There are two major water use issues to consider when examining ethanol production: 1) water used to grow feedstock grain, and 2) water used in the grain-to-ethanol conversion process. In the western part of Kansas, grain sorghum is usually grown under dry-land conditions; that is, without irrigation. Water to produce the grain is supplied by resident soil water and natural rainfall during the growing season. Although corn is grown in Eastern Kansas under dry-land conditions, in Western Kansas most of the corn is irrigated.

Water to Produce Corn

In 2005, Kansas irrigated 1.51 million acres of corn (Kansas Agricultural Statistics Service). A majority of those acres were irrigated with center pivot systems, assumed to have about a 95 percent efficiency rate (Staggenborg 2007). The goal of irrigation is to keep soil water availability from limiting crop growth and reproduction. Soil water can come from water stored in the root zone, rainfall during the growing season, and irrigation. Too little soil water will stress the plants, but excess water from irrigation wastes water, energy, and nutrients as well as unnecessarily deplete the water source (Rogers and Alam 2007). A hypothetical irrigation schedule was developed to determine water usage for this study. Historical rain and evapotranspiration data ranging from 1985 to 2006 were collected for four Western Kansas locations: Colby, Garden City, Hays, and Tribune.

Evapotranspiration (ET) accounts for water which evaporates from the surface of the soil as well as moisture which is transpired from the plant. ET data are a composition of various climatic data including solar radiation, air temperature, relative humidity, and wind speed. Reference ET data are adjusted by a crop coefficient which accounts for the differences among plant types. The resulting Crop ET is dependent on canopy cover, crop type and variety, and plant maturity (Rogers and Alam 2007). Using ET data to create an irrigation schedule is similar to balancing a checkbook—ET withdrawals are balanced against water deposits from existing soil water, rainfall, and irrigation. Thus, through scheduling, the amount and timing of irrigation water application needed to raise a corn crop can be determined.

Critical factors affecting an irrigation schedule are the depth of the crop root zone, soil type water holding capacity, and allowable depletion (Rogers and Alam 2003). Corn was assumed to have a root zone depth of four feet. Silt loam soil, which covers most of Western Kansas, typically has a 2-inch per foot water holding capacity. In this case, the soil was determined to have a water holding capacity of 8 inches (Staggenborg 2007). The amount of allowable irrigation water depletion for each location was assumed to be a constraint. Kansas State Research and Extension irrigation software, KanSched, was used to determine irrigation water needs for growing corn in Colby, Garden City, Hays, and Tribune. Microsoft Excel's Solver was used to find the minimum amount of water needed to keep the soil water availability at or above 50 percent. If water availability falls below 50 percent, irrigation must occur on that day or corn will experience stress. Table 1 shows a summary of the four outputs from KanSched: Reference ET, Crop ET, Rain, and Irrigation, for each location. Daily irrigation rates ranged from 0.08 to 0.34 inches, depending on location, date, and growth stage. Calculated irrigation rates were slightly higher than those reported in the Rogers and Alam 2003 study which determined that the optimal irrigation rate for fields with deep silt loams soils was 0.25 inches per day.

Results from the KanSched model are reported in Appendix A. Each table lists water inputs and outputs for all four locations. In Appendix A, Table 1 water usage is reported in gallons per acre. Appendix A, Table 3 shows the necessary water inputs and outputs in gallons per bushel. An illustration of a water budget to raise irrigated corn in Colby, Kansas is shown in Figure 1 below. Results from the KanSched model suggested it would take 2,159 gallons of irrigation water in addition to natural rainfall to produce one bushel of corn near Colby, Kansas. An ethanol plant will convert one bushel of corn into about 2.7 gallons of ethanol, therefore approximately 800 gallons of irrigation water are needed to produce one gallon of ethanol. It should be pointed out that the production of a bushel of Colby corn would still require 2,159 gallons of irrigation water if it were to be fed to livestock instead of utilized for ethanol production.

Ethanol Plant Water Consumption

Corn dry milling (sometimes referred to as dry grind) is the process most commonly used for ethanol production. Corn wet mills can also produce ethanol, but are usually configured to produce higher value products such as high fructose corn syrup. Corn dry milling ethanol plant yields have improved in recent years from about 2.65 gallons of ethanol per bushel of corn processed to 2.8 gallons or more for newer plants.

Water usage in dry milling ethanol plants can be broken down into two categories: process water and non-process water. Process water, as suggested by the name, is water that has contact with grain in processes such as mixing slurry, fermentation, and saccharification. Process water typically makes up one-third of the water required by a plant. The remaining two-thirds of water utilized in making ethanol does not come in contact with any form of the grain. Approximately 90 percent of non-process water is used in heat transfer and cooling systems (Stanich 2007).

Water sources for ethanol plants include groundwater, surface water, and municipal water. Depending on proximity to source, an ethanol plant may be able to use gray water, the effluent flow from a municipal wastewater plant (Stanich 2007). With proper treatment ethanol plants may be able to utilize other low quality water, such as sewage treatment plant effluent or recycled water from animal feedlots (Keeney and Mueller 2006). However, groundwater is the main source of water for most ethanol plants, not only because it is readily available, but also because it usually is of higher quality than water from alternative sources and less expensive than municipal water (Mowbray and Hume 2007).

A 40 million gallon per year ethanol plant model was developed using SuperPro Designer®. The simulation model was obtained from the website of Intelligen, Inc. (*See www.intelligen.com*). Calculated process and non-process water usage for heat transfer and cooling was 4.23 gallons of water per gallon of ethanol produced by the simulated plant.

The actual amount of water needed to produce a gallon of ethanol varies from plant to plant. Minnesota is one of the few states to collect records of water used by ethanol plants. Minnesota Department of Natural Resources records show ethanol plant water usage to vary from 3.5 gallons to 6.0 gallons of water per gallon of ethanol produced. Average water usage in the Minnesota plants decreased from 5.8 to1 in 1998 to 4.2 to 1 in 2005 (Keeney 2006). A USDA survey of ethanol plants in 2002 showed water usage per gallon of ethanol produced varied from less than 1 gallon to 11 gallons and averaged 4.7 gallons (Shapouri and Gallagher 2005).

An effort was made to obtain water use information from Kansas ethanol plants for this study. However, actual water use data was obtained from only one plant; a newer plant, which averaged 3.07 gallons of water per gallon of ethanol produced. Another Kansas plant recently installed a closed cooling system which significantly reduced evaporative water loss. Not enough data had been collected to calculate the impact of the new cooling system on ethanol per gallon water usage.

Ethanol-Related Impacts on Kansas Crop and Livestock Industries

In this analysis of grain-based ethanol production in Kansas, feedgrain use for both bioenergy and livestock feeding was examined, as well as the production and maximum potential use of ethanol process co-products (wet and/or dry distillers grain) in livestock feed rations. The use of Kansas feedgrains for either out of state shipments or exports outside the U.S., and grain stocks at the beginning or end of the calendar year were not quantified in this study. Any residual amount of feedgrain supply over use in livestock feeding or grain-based ethanol production was assumed to be available for either export or accumulation of reserve grain stocks.

Kansas Ethanol and Distillers Grains Production Capacity

Ethanol production has been a consumer of feed grains in Kansas and other central and western Corn Belt states for a number of years prior to 2005. In this study, detailed information of feed grain usage and distiller's grain production by crop reporting district are analyzed for the 2005-2007 period because of the unavailability of crop reporting district – level data for earlier years (Nebraska Energy Office). After obtaining the locations of the ethanol plants and their annual capacity in terms of millions of gallons, it was assumed that these plants could use either corn or grain sorghum interchangeably as a feedstock. It was also assumed that these ethanol plants were producing at their full stated capacity (i.e. 100% capacity). In actuality, some plants were likely producing at either more or less than full capacity at different times during the 2005-2007 time period. It was assumed that 0.37 bushels of corn or grain sorghum were required to produce a gallon of ethanol, or conversely, that 2.7 gallons of ethanol were produced from one (1) bushel of feedgrains. It was also assumed that 17 pounds of distiller's grains were produced per bushel of feedgrains used in the ethanol production process.

The production capability of the Kansas grain-based ethanol industry increased from 7 plants with 172,327,500 gallons of ethanol production capacity in 2005, to 8 plants with 212,287,500 gallons capacity in 2006, and to 10 plants with 322,177,500 gallons capacity in 2007 (Appendix B, Table 1). The south central (CRD #60) and southwest (CRD #30) regions of Kansas had the largest ethanol production capacity in 2007 (80 million and 67 million gallons capacity, respectively). These areas were followed in ethanol production capacity by the central (CRD #50 – 48 mln. gal.), west central (CRD #20 – 46 mln. gal.), north central (CRD #40 – 40 mln. gal.), and east central (CRD #80 – 35 mln. gal.)

reporting districts of Kansas. Kansas feedgrain use for ethanol production increased from 64 mln. bu. to 119 mln. bu. from year 2005 to 2007. Planned additional ethanol production capacity at the end of 2007, if completed, would increase Kansas feedgrain use for ethanol production by an additional 68 million bushels.

As a result of these Kansas ethanol plants, distillers dried grain (DDG) production capacity increased from 1,085 million lbs. to 2,029 million lbs. from 2005 to 2007 (Appendix B, Table 1). Alternatively, wet distillers grain (WDG) production capacity (which is the wet form of DDGs sold directly from ethanol plants without moisture removed) increased from 32,678 truckloads in 2005 to 61,094 truck loads in 2007. A truckload of WDGs is assumed to weigh 25 tons.

Kansas Feedgrain and Livestock Production

Information was gathered on feedgrain and livestock production for crop reporting districts in Kansas and other feedgrain producing states in the central and western Corn Belt for the 1997-2007 period. Corn and grain sorghum were the two types of feedgrains included in this study. Livestock species studied for their estimated feed use include dairy cattle, beef cows and calves (both pre-feedlot and non-fed), cattle in feedlots, hogs and poultry. Data sources for grain and livestock numbers include online information from National Agricultural Statistics (NASS) within the United States Department of Agriculture (USDA) as well as annual USDA-NASS *Agricultural Statistics* publications.

Crop reporting district (CRD) level data for feedgrain supplies, ethanol production and livestock numbers were used to better represent possible intra-state regional impacts of ethanol production in Kansas. Other central and western Corn Belt states examined include those that either border Kansas or whose use of feedgrains and supply of ethanol co-products are likely to directly impact Kansas grain and livestock industries. These states include Iowa, Nebraska, Colorado, Texas, Oklahoma, South Dakota, Missouri, and Minnesota. Some states have either not provided livestock data on a district basis or have combined district observations to protect the privacy and identity of a limited number of livestock producers. In those cases, the reported livestock numbers were assumed to be distributed evenly across those states' respective reporting districts.

During each year of the 1997-2007 period, on a statewide basis Kansas feedgrains have exhibited a net positive supply-demand balance (Appendix B, Table 2). This net positive balance is calculated before accounting for grain stocks available at the beginning of year year, for grain moved (or exported) out-of-state, and for unused carryover grain stocks at the end of each year. However, on a crop reporting district basis, some regions of Kansas have had relatively tight net feedgrain balances and at times net feedgrain deficits during the 1997-2007 period. During year 2006, after ethanol plants were established in the state, a net feedgrain deficit occurred in West Central Kansas (CRD #20), and net feedgrain balances tightened considerably in Southwest (CRD #30), Central (CRD #50) and East Central (CRD #80) Kansas. Recent establishment of ethanol plants in North Central (CRD #40), South Central (CRD #60) and East Central (CRD #80) Kansas appear to have tightened net feedgrain balances in these regions since 1997.

From Kansas' perspective, it is relevant to look at the feed grain balance in surrounding states and crop reporting districts. The majority of districts in Colorado, all of the districts in Oklahoma, and the majority of districts in Texas are already at a negative feed balance. With projected expansion in ethanol production in the central and western Corn Belt, at least one crop reporting district in each of the following states: Iowa, Nebraska, Minnesota, Missouri, and South Dakota are calculated to have a negative feed grain balance. While this paper focuses on the impacts of Kansas grain-based ethanol production, future plans are to broaden the scope of the study to include ethanol-related impacts in these other central and western Corn Belt states.

Livestock Feed Use

Iowa livestock enterprise budgets were used to provide estimates of feedgrain and distillers grains use in feed rations for beef and fed cattle, dairy cattle and hogs (Table 2) (Iowa State University). Estimated feedgrain consumption by poultry of 1.0625 bushels of corn annually was taken from other published ISU studies.

The major saleable by-product of grain-based ethanol production is distiller's grains. As stated above, approximately 17 pounds of distiller's grains in various forms are produced for each bushel of corn used in ethanol production. By-product forms are: Distillers Dried Solubles (DDS), Distillers Dried Grains (DDG), Condensed Distillers Solubles (CDS), Distillers Wet Grains (DWG), and Distillers Dried Grains with Solubles (DDGS) (Iowa Department of Agriculture).

In 2007 the estimated DDG production in Kansas (2,028 million lbs.) equaled 38% of the total maximum use of DDGs in livestock rations (5,340 million lbs.) (Appendix B, Table 3). The potential for use of DDGs in livestock rations were calculated using Iowa State University feed ration recommendations (Table 2). The largest potential demand for DDG use in livestock feeding is found in southwest Kansas (CRD #30), a concentrated center for cattle feeding enterprises. East central Kansas (CRD #80) has the largest potential to export DDGs for use by livestock feeders in other egions both in and outside of Kansas.

The determination of optimal levels of distiller's grains to include as a livestock feed ingredient for various livestock species is presently a topic of intense research. In the grain-based ethanol production process, all the starch is removed from feedgrains. What remains is composed of protein, lipid, fiber, vitamins, and minerals, concentrated to approximately three times the level found in unprocessed corn. The high concentration of corn oil in distiller's grain may affect meat quality and limit its feed value for some livestock species. For poultry, high fiber content limits DDG use in feed rations. There is also concern about the presence in distillers grains of non-grain processing agents used in ethanol production. Companies are currently trying to commercialize processes that would improve the feed value of distiller's grains to expand the use markets and increase revenues for ethanol producers (Johnson).

Supply Sensitivity of Net Feedgrain and DDG Feed Equivalents

The net balance of feedgrains plus DDG feed equivalents is sensitive to potential shortfalls is Kansas feedgrain production (Appendix B, Table 4). By conservatively assuming that DDGs have 33% of the feed value of feedgrains and by adding feedgrain production and DDG feed equivalents produced together, the total available feedgrain equivalent supply can be calculated. Subtracting the total use of feedgrains (less exports and stocks) allows for calculation of the total net balance of feedgrain equivalents for each crop reporting district in Kansas. These results are similar to the simple feedgrain net balance (Appendix B, Table 2), but are adjusted for the equivalent feed value of DDGs to feedgrains.

If feedgrain supplies were reduced by first 10% and then 33% because of either weather-related crop production problems, shifts in crop acreage from 2005-2007 levels, or other production factors, the net balance of feedgrain equivalents would tighten considerably (Appendix B, Table 4). The West Central (CRD #20), Southwest (CRD #30), Central (CRD #50), and East Central (CRD #80) would develop near breakeven or in some cases deficit feedgrain equivalent balances if feedgrain supplies were to decline 10% and especially 33% from 2005-2007 levels.

Effects of Weather in Kansas Non-irrigated Corn Production

Variability in weather conditions are a common source of risk in agriculture, causing uncertainty in respect to crop yields (Park and Sinclair, 1993). It is necessary to understand the effects of potential precipitation and temperature variability upon crop production processes before entering into in the decision making process. In this study, a multiple-regression model was built and analyzed with the objective of determining the impact of precipitation and temperature on corn yields in Kansas. This analysis was performed under the knowledge that there were several other factors likely affecting Kansas corn yields. However, for practical purposes “ceteris paribus”, i.e. “all else being equal” is assumed.

Crop Reporting District Data

In this analysis, Kansas crop reporting district-level data is used, representing nine (9) regions of the state: CRD #10 - Northwest, CRD #20 - West Central, CRD #30 - Southwest, CRD #40 - North Central, CRD #50 - Central, CRD #60 - South Central, CRD #70 - Northeast, CRD #80 - North Central, and CRD #90 - Southeast. Thirty six (36) years of data (1972 to 2007) were considered in order to capture trends or cycles in precipitation and temperature behavior that are relevant to Kansas corn production processes.

The USDA National Agricultural Statistics Services (NASS) website was a primary source of irrigated and non-irrigated corn yield data for each crop reporting district. This study focuses on how weather impacts non-irrigated corn yields, avoiding the mitigating impact of irrigation upon corn yields under irrigation. Monthly data on growing season precipitation and temperature for each crop reporting district was obtained from the National Climatic Data Center. Corn yields were detrended to adjust for technology effects, i.e. genetic improvements corn seed production capability over time. According to Swinton and King (1991) "…crop yield time-series data are detrended in order to remove technology bias from estimates of the underlying probability distribution". This procedure was completed using SAS ("Statistical Analysis Software").

Methodology

Effective crop-weather models are dependent on the selection of independent variables and functional forms. Quadratic form crop-weather models allow for the representation of diminishing returns in regards to yield-impacting precipitation and temperature effects (Vulgamore 1998). These assumptions explain the possibility that at some point in the growing season of the crop, a high level of precipitation or high temperature will contribute to the reduction of crop yields rather than increases. The variables included in the regression model correspond to the precipitation and temperature of those months of relevant incidence in the corn growing season: April, May, June, July, August and September.

The log linear functional form was chosen for this crop-weather model. The log linear form allowed for determination of the impact of annual precipitation on yields over time separate from the impact of trend yield increases in water use efficiency (Vulgamore

1998). Selection of the empirical corn yield model was based on the goodness of fit coefficient or R^2 and on the significance of the variables. According to the p-values, the variables for September precipitation and temperature were not statistically significant. Because of this the final crop weather model used April, May, June, July and August precipitation and temperature variables. The empirical corn yield model (1) is shown below. Variables for model (1) are described with accompanying summary statistics : mean, standard deviation, minimum and maximum for each variable in the period (1972-2007) (Appendix C, Table 1).

$$
\begin{aligned}
ln\ (Y)_{it} = {} & \beta_0 + \beta_1(APRP)_{it} + \beta_2(APRP)^2_{it}\ \beta_3(MAYP)_{it} + \beta_4(MAYP)^2_{it} + \beta_5(JUNP)_{it} + \beta_6(JUNP)^2_{it} + \\
& \beta_7(JULP)_{it} + \beta_8(JULP)^2_{it} + \beta_9(AUGP)_{it} + \beta_{10}(AUGP)^2_{it} + \beta_{11}(APRT)_{it} + \beta_{12}(APRT)^2_{it} \\
& \beta_{13}(MAYT)_{it} + \beta_{14}(MAYT)^2_{it} + \beta_{15}(JUNT)_{it} + \beta_{16}(JUNT)^2_{it} + \beta_{17}(JULT)_{it} + \beta_{18}(JULT)^2_{it} \\
& + \beta_{19}(AUGT)_{it} + \beta_{20}(AUGT)^2_{it} + \varepsilon_{it} \qquad (1)
\end{aligned}
$$

Results

The multi-regression results are illustrated in Appendix C, Table 2. The R^2 coefficient of 0.5525 indicates that 55.25% of the variability in the natural log corn yield is explained by the precipitation and temperature variables. The results indicated that April, May, Jun and July precipitation variables, April and June temperature variables, July and April squared precipitation variables and April and June squared temperature variables are statistically significant (Refer to Appendix C, Table 4 to see the significance level). Thus, the variables without statistical significance are August precipitation and squared precipitation, July temperature and squared temperature and May, Jun and August squared precipitation. Figure 2 shows a comparison between the actual corn yield values and predicted values. The predictive accuracy of the model is mixed, with some accurate and some inaccurate corn yield predictions. It is important to note that the predictive error of the model is small in comparison to the actual year to year variability of corn yields.

The model coefficients explain the effects of precipitation and temperature in corn yield. Corn yield model (1) calculated the marginal effect of each variable upon corn yields by taking the first derivative of natural log of corn yield with respect to each variable. Equation (2) shows the mathematical calculation of the marginal effect for April precipitation in the same manner as will be applied to other variables in the model.

$$\begin{aligned} \textit{Marginal Effect} &= (\beta_1 + 2 * \beta_2 * (APRP)) * e^{(Y)} \\ &= (\beta_1 + 2 * \beta_2 * (APRP)) * \textit{Predicted Value of corn yield} \end{aligned} \tag{2}$$

Table 3 shows the marginal effect of temperature and precipitation in the 2002 corn yield for the D90 Southeast district. The real corn yield value is 100.12 bu/acre and the predicted is 98.68 bu/acre.

The marginal increase in corn yield due caused by incremental changes in precipitation and temperature levels is shown. Differences in yield response to variations in precipitation and temperature are shown, including diminishing returns at higher levels of each factor. In April, an increase of 1 inch of precipitation (considering that the precipitation in this month for 2002 is 4.54 inches), will increase the corn yield in 8.88

bu/acre, all else being held constant. An increase in temperature of 1 °F (considering that the temperature in this month for 2002 is 57.70 °F), will decrease the corn yield by 30.64 bu/acre. July and April precipitation have a direct positive relationship with yield. An increase in the amount of precipitation in these months will increase the amount of yield at a decreasing marginal rate. Increases in June and May temperature also corn yields.

The monthly values of precipitation and temperature required for optimum corn yields were calculated from this model (Table 4). These were estimated by estimating the marginal effects for each weather factor in the manner of equation (2), setting each equal to zero, and solving for the optimal monthly precipitation and temperature values.

Truck Transportation Impacts of Ethanol Inputs and Co-Products.

A typical, "modern" dry-mill ethanol plant requires the movement of a significant amount of commodities in order for the plant to merely meet their nameplate capacity production. The dry-mill plant modeled to calculate the total demand for truck transportation for this study is located in Kansas. This plant utilizes the starch from grain sorghum and wheat to produce its primary outputs, ethanol and wet distiller's grain with soluble (DGS) (approximately 55% moisture), so with respect to its primary inputs and wet distiller's grain, it is atypical when compared to the more traditional corn-belt plant that solely utilizes corn and markets dried distiller's grain (DDGS) (approximately 10% moisture).

Because this plant is located in close proximity to feed yards, it can market its distiller's grain in wet form, hence reducing its natural gas costs. Also, the plant has the ability to avoid the high cost structure of the rail system by shipping 50% of its denatured ethanol via truck to a blender located 150 miles away. Specifically, this plant is assumed to process 13 and 5 million bushels of grain sorghum and wheat per year, respectively, and it annually markets 52 million gallons of denatured ethanol and roughly 167 thousand tons of wet distiller's grain. Only the grain sorghum processed in this plant yields distiller's grain, which is why this plant has less distiller's grain output than a similar sized ethanol plant utilizing corn and/or grain sorghum.

Table 5 shows the total input, output, and number of truckloads required to keep the plant in operation. Truckload numbers were calculated by taking the respective input/output and dividing it by the maximum freight capacity allowed by the Kansas Department of Transportation. Maximum legal freight capacity in Kansas is 950 bushels of grain, 25 tons of wet distiller's grain, and 9,000 gallons of ethanol. As noted in the table, this plant is assumed to market 90% of its distiller's grain as wet and distribute 50% of its ethanol via truck and 50% via rail.

In order to calculate the total transportation payments generated by the ethanol plant, the total costs of hauling the inputs and outputs were estimated. This plant receives its grain from a distance of no more than 60 miles with an average one-way haul of about 30 miles. This plant also hauls its wet distiller's grain approximately 30 miles and the 2,889 truckloads of denatured ethanol hauled are taken to a blender approximately 150 miles from the plant. Given these mileages and 2007 average costs for the capital equipment and trucking inputs such as fuel, oil, tires, insurance, and labor, the average cost per truck with respect to each material hauled was calculated.

Table 6 depicts these annual costs and mileages driven per truck on an annual basis. We assumed that due to OSHA regulations, a tractor-trailer operator could not work for more than 2,000 hours on an annual basis and that each truck was fully operated for 2,000 hours annually solely hauling one of the three commodities listed, with the balance of time being devoted towards ordinary maintenance.

Given the total demand for trucking and the cost estimates per truck indicated in Tables 5 and 6, respectively, the total number of full-time trucks required to meet the plant's needs and the subsequent total annual payments to the trucking industry that the plant created were then calculated. Table 7 shows the breakdown of number of loads of each input/output, the average duration of each load, including an unloaded backhaul, for each load given the above mileages.

As indicated by Table 7, payments to the trucking sector from this plant would amount to approximately $4.15 million. The plant's operation requires the full-time services of 37 tractor-trailers and operators. Note that not all of these payments would come from the ethanol plant. That said, this is the estimate of what total payments to the trucking industry resulting in the plant's operation would be.

The estimates presented in this study were for a specific ethanol plant in Kansas. However, the framework developed in this study can be utilized to account for each plant in Kansas given their production and marketing characteristics. Future plans for this study are to calculate estimates of the total payments to the trucking industry by ethanol plants in Kansas and other central and western Corn Belt states.

Total trucking requirements and total payments transferred to the trucking sector are very sensitive with respect to the average distance and length of each haul as well as to the production and marketing characteristics of the plant. For example, if the plant hauled 0% or 100% of its ethanol via truck, the total number of trucks required will fluctuate ±9.4 and payments of ±$1.2 million. Depending on how much distiller's grain is marketed in wet form, the number of loads required can fluctuate or decrease by as much as 1,557 fewer loads. This change from marketing wet to dry distillers grains would reduce total truck / co-product hauling demand by 5.6%. Also, note that this plant utilized wheat starch in their production process.

If grain sorghum was solely used to produce the given level of ethanol output, WGS, and hence, trucking demand would increase. Therefore, information on each plant's production and marketing characteristics needs to be known for further state-wide analysis. It is the goal of this study to eventually estimate ethanol-related trucking demand and associated payments to the trucking sector for each ethanol plant in Kansas, and then to estimated these measures for on a statewide basis.

Grain Elevator Survey of Ethanol Development Impacts

A mail survey was conducted among Kansas grain handlers to determine the extent to which feedgrain-based ethanol production may have impacted intra-state grain markets and trade. This confidential survey was conducted by faculty and staff of the Department of Agricultural Economics at Kansas State University.

A four page survey was sent to a selected sample of Kansas grain elevators. The population sample was obtained from the 2008 Official Directory of the Kansas Grain and Feed Association. The survey random sample was drawn from a population of approximately 475 grain elevators that were located within 100 miles of existing grain ethanol plants in the state. Addresses were drawn randomly without bias in regards to size, rail-access, business type, or geographic location in the state (other than location within a 100 mile radius of a Kansas ethanol plant). The survey was conducted during May-June, 2008.

Questions for the grain handler's survey were based on the operation's relationship to the ethanol industry, in addition capacity and usage-related questions were included. Most questions were pre-empted with a subject-like statement, such as "Elevator Capacity" or "Ethanol Co-Products". Observations from those reviewing the survey felt this additional information minimized confusion regarding the question to follow by placing it in context. A condensed, edited version of the survey is provided in Appendix D.

Conclusions

The development of grain-based ethanol production in Kansas has had a marked impact upon the feedgrain and livestock industries of the state. The increased focus on feedgrain production stemming from ethanol development impacts the use and sustainability of Kansas water resources, and has changed the proportional mix of crops grown in the state. The need to handle increased amounts of feedgrains and to transport them to ethanol plants has affected the functional role of local grain elevators as well as the directional flow of grain within the state. The grain trucking industry has been dramatically affected by the increase in demand for moving both feedstock inputs and co-product outputs to and from ethanol plants in the state.

The broader market impact of high feedgrain prices due to ethanol demand as well as other factors (strong exports, steady livestock feed demand, unavailability of feed quality wheat as a substitute for feedgrains in livestock rations, etc.) have had a negative impact on the profitability of livestock feeding enterprises, both in Kansas and elsewhere. Furthermore, the risk of weather-induced short feedgrain crops in future years brings uncertainty to industries involved in each of the three primary uses of feedgrains at the present time (i.e. the livestock , export, and ethanol industries).

These results provide evidence of the magnitude and direction of the impact of ethanol development upon Kansas agriculture. Future work will focus on the observations of individuals involved in the Kansas grain market, such as grain elevator and ethanol plant operators. It will also focus on specific, localized impacts of ethanol plants upon grain and livestock enterprises and markets, and upon economic activity in these regions.

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Table 1. KanSched Calculated Evapotranspiration, Rain, and Irrigation Rates.

Location	Statistic	Reference ET	Crop ET	Rain	Irrigation
Colby	Max	0.37	0.42	0.13	0.32
	Min	0.20	0.00	0.08	0.08
	Total	**29.63**	**28.03**	**10.83**	**12.85**
Garden City	Max	0.38	0.43	0.13	0.33
	Min	0.23	0.00	0.08	0.14
	Total	**30.65**	**28.94**	**10.94**	**13.50**
Hays	Max	0.30	0.34	0.14	0.23
	Min	0.21	0.00	0.09	0.09
	Total	**25.31**	**23.83**	**11.25**	**8.37**
Tribune	Max	0.38	0.44	0.13	0.34
	Min	0.21	0.00	0.08	0.14
	Total	**30.27**	**28.75**	**10.78**	**13.57**

Table 2. Feedgrain and Distillers Grain Consumption in Livestock Feed Rations

	Yearly Consumption per head		
	Feedgrain Use in Rations without Distillers Grains (bushels)	Feedgrain Use in Rations with Distillers Grains (bushels)	Distillers Grain Use in Feed Rations (pounds)
Hogs	9.6	9.0	32.0
Beef Cattle	4.0	4.0	---
Dairy	113.0	76.5	2,738.0
Cattle on Feed	67.0	50.0	1,900.0
Poultry	1.0625	1.0625	---

(Source: Iowa State University – Livestock Budgets)

Table 3. Marginal Effect on Corn Yields of Weather Factors in Southeast Kansas in 2002

		Marginal Change in Yield (bu/acre)				
		April	May	June	July	August
Precipitation	1	8.88	5.63	4.87	18.23	-1.47
(Additional inches)	2	7.45	5.08	4.54	15.92	-0.42
	3	6.02	4.52	4.2	13.61	0.63
	4	4.59	3.96	3.87	11.3	1.68
Temperatue	1	-30.64	28.31	50.75	-2.92	-39.27
Additional ° F	2	-32.06	27.88	50.05	-2.88	-38.78
	3	-33.27	27.44	49.36	-2.85	-38.28
	4	-31.06	27.01	48.67	-2.82	-37.79

Table 4. Optimal Values of Crop Weather Factors in Determining Corn Yields

	Precipitation (inches)	Temperature (° Fahrenheit)
April	7.50	52.67
May	10.50	72.75
June	13.25	65.12
July	8.67	88.23
August	2.60	100.75

Table 5: Total Daily and Annual Input and Required Truckloads.

	Input Demand (1,000 Bu)		Truckloads	
Input	Daily	Annually	Daily	Annually
Grain Sorghum	35.6	13,000	37.0	13,684
Wheat	13.7	5,000	14.4	5,263
	Production		Truckloads	
Output	Daily	Annually	Daily*	Annually*
DGS (tons)	456.0	166,595	16.4	5,997
Ethanol (1,000 gal)	142.4	52,000	7.9	2,889
			Daily*	Annually*
		Total Truckloads	76	27,834

**Assumption: 90% of DGS is marketed at 66% moisture and 50% of ethanol production is hauled via truck.*

Table 6: Total Annual Trucking Cost Breakdown Per Truck

	Commodity		
Ownership Costs	Grain	Ethanol	DGS
Capital recovery (interest and depreciation)	$19,972	$21,530	$26,205
Taxes, insurance, license	8,400	8,500	8,800
Total ownership cost	$28,372	$30,030	$35,005
Operating Costs			
Repair	$2,500	$2,500	$2,500
Tires	2,458	3,809	1,966
Fuel and lubrication	42,000	65,100	33,600
Labor	30,000	30,000	30,000
Total operating cost	$76,958	$101,409	$68,066
Total Ownership and Operating	$105,329	$131,439	$103,071
Annual Miles Driven	60,000	93,000	48,000

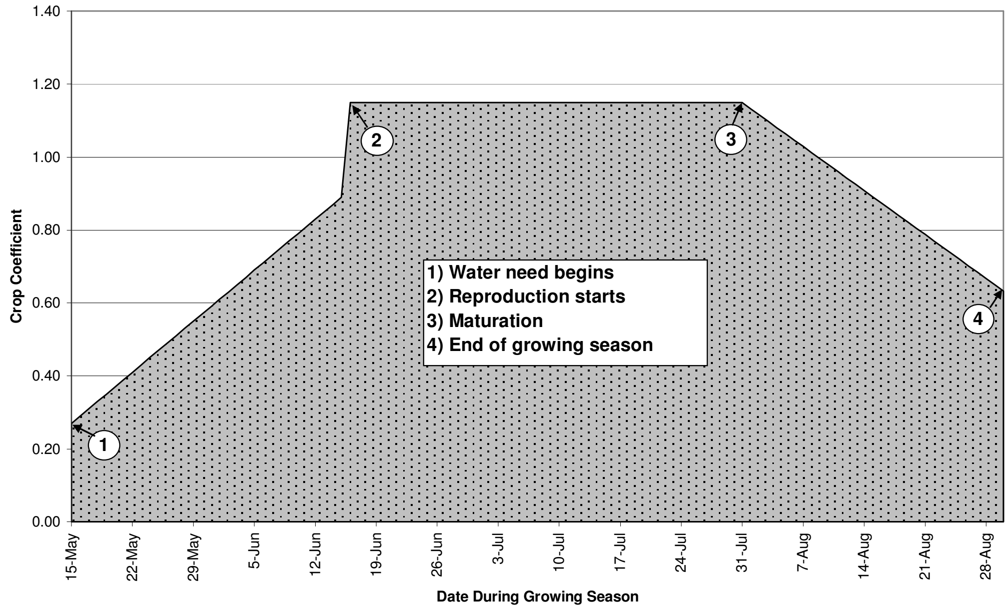
**Assumption: Annual Truck Operation=2,000 Hours*

Table 7: Breakdown of Total Payments to the Trucking Industry

Commodity	Truck Loads	Average Duration	Trucks Required*	Cost Per Truck	Total Cost
Grain Sorghum	13,684	2.0 hrs.	13.7	$105,329	$1,441,350
Wheat	5,263	2.0 hrs.	5.3	$105,329	$554,366
DGS	5,997	3.0 hrs.	9.0	$103,071	$927,238
Ethanol	2,889	6.5 hrs.	9.4	$131,439	$1,234,069
		Total	37		$4,157,023

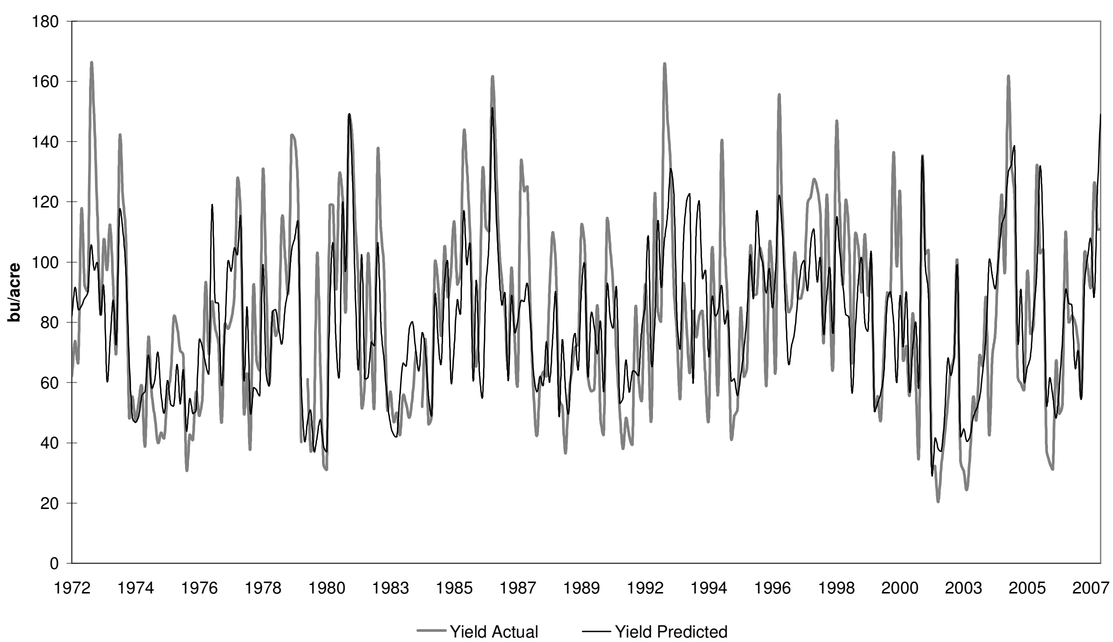
**FTE=2,000 Hours*

Figure 1. Scheduled Season Crop Coefficient for Colby, Kansas, 1985-2006.



Source: KanSched

Figure 2. Actual Versus Predicted Kansas Non-irrigated Corn Yields



Appendix A

Appendix A. Table 1. Per Acre Corn Water Requirements and Usage

	Inputs (gallons/acre)				Outputs (gallons/acre)					
Location	Rain	Irrigation	Initial Subsoil Moisture	Total Inputs	Reference ET	Crop ET	Runoff	Dry-down	Remaining Subsoil Moisture	Total Outputs
Colby	294,078	348,929	217,232	860,239	804,573	761,127	32,150	325	66,636	860,239
Garden City	297,065	366,579	217,232	880,876	832,270	785,837	33,182	333	61,524	880,876
Hays	305,483	227,279	217,232	749,993	687,268	647,080	26,638	268	76,007	749,993
Tribune	292,720	368,480	217,232	878,432	821,952	780,678	33,060	285	64,409	878,432

Appendix A. Table 2. Per Bushel Corn Water Requirements and Usage

	Inputs (gallons/bushel)				Outputs (gallons/bushel)					
Location	Rain	Irrigation	Initial Subsoil Moisture	Total Inputs	Reference ET	Crop ET	Runoff	Dry-down	Remaining Subsoil Moisture	Total Outputs
Colby	1,819	2,159	1,344	5,322	4,977	4,708	199	2.01	412	5,322
Garden City	1,797	2,217	1,314	5,328	5,034	4,753	201	2.01	372	5,328
Hays	2,292	1,705	1,630	5,626	5,155	4,854	200	2.01	570	5,626
Tribune	2,066	2,600	1,533	6,199	5,800	5,509	233	2.01	455	6,199

Appendix B

Appendix B. Table 1. Kansas Grain Based Ethanol and Distillers Dried Grains Production Capacity (2005-2007)

Year	Kansas Crop Reporting Districts	Current Number of Ethanol Plants	Current Ethanol Plant Capacity (gallons/yr)	Feedgrain Use: Current Plant Capacity (bushels/year)	DDG Production Capacity (1,000 lbs.)	WGS Production: WDG 25 ton Truckloads	Number of Plants Expanding or New	Additional Plant Capacity Construction (gallons/yr)	Feedgrain Use: Additional Plant Capacity (bushels/year)
2005	#10 (NW)	0	0	0	0	0	0	0	0
	#20 (WC)	2	46,453,500	17,205,000	292,485	8,809	0	0	0
	#30 (SW)	1	11,988,000	4,440,000	75,480	2,273	0	0	0
	#40 (NC)	0	0	0	0	0	1	39,960,000	14,800,000
	#50 (C)	1	47,952,000	17,760,000	301,920	9,093	0	0	0
	#60 (SC)	1	24,975,000	9,205,000	157,250	4,736	0	0	0
	#70 (NE)	1	5,994,000	2,220,000	37,740	1,137	0	0	0
	#80 (EC)	1	34,965,000	12,950,000	220,150	6,630	0	0	0
	#90 (SE)	0	0	0	0	0	0	0	0
	STATE	**7**	**172,327,500**	**63,825,000**	**1,085,025**	**32,678**	**1**	**39,960,000**	**14,800,000**
2006	#10 (NW)	0	0	0	0	0	0	0	0
	#20 (WC)	2	46,453,500	17,205,000	292,485	8,809	0	0	0
	#30 (SW)	1	11,988,000	4,440,000	75,480	2,273	2	165,050,000	61,050,000
	#40 (NC)	1	39,960,000	14,800,000	251,600	7,578	0	0	0
	#50 (C)	1	47,952,000	17,760,000	301,920	9,093	0	0	0
	#60 (SC)	1	24,975,000	9,205,000	157,250	4,736	1	54,945,000	20,395,000
	#70 (NE)	1	5,994,000	2,220,000	37,740	1,137	0	0	0
	#80 (EC)	1	34,965,000	12,950,000	220,150	6,630	0	0	0
	#90 (SE)	0	0	0	0	0	0	0	0
	STATE	**8**	**212,287,500**	**78,625,000**	**1,336,625**	**40,256**	**2**	**219,995,000**	**81,400,000**
2007	#10 (NW)	0	0	0	0	0	1	19,980,000	7,400,000
	#20 (WC)	2	46,453,500	17,205,000	292,485	8,809	0	0	0
	#30 (SW)	2	66,933,000	24,790,000	421,430	12,692	1	109,890,000	40,700.000
	#40 (NC)	1	39,960,000	14,800,000	251,600	7,578	0	0	0
	#50 (C)	1	47,952,000	17,760,000	301,920	9,093	1	54,945,000	20,350,000
	#60 (SC)	2	79,920,000	29,600,000	503,200	15,155	0	0	0
	#70 (NE)	1	5,994,000	2,220,000	37,740	1,137	0	0	0
	#80 (EC)	1	34,965,000	12,950,000	220,150	6,630	0	0	0
	#90 (SE)	0	0	0	0	0	0	0	0
	STATE	**10**	**322,177,500**	**119,325,000**	**2,028,525**	**61,094**	**3**	**184,815,000**	**68,450,000**

Appendix B. Table 2. Kansas Feedgrain Supplies, Demand and Net Usage Balance (1997-2007)

Year(s)	Kansas CRDs / State	Feedgrain Production (bushels)	Livestock Use of Feedgrains (bushels)	Ethanol Use of Feedgrains (bushels)	Total Use of Feedgrains (w/o Exports & Stocks) (bushels)	Net Balance Feedgrain Use (w/o Exports & Stocks) (bushels)	% FG Use of Supply
Average 1997-2004	#10(NW)	66,661,375	11,202,086	---	11,202,086	55,459,289	18.9%
	#20(WC)	47,111,625	32,378,817	---	32,378,817	14,732,808	80.8%
	#30(SW)	168,970,875	95,963,992	---	95,963,992	73,006,883	58.4%
	#40(NC)	57,958,875	7,693,129	---	7,693,129	50,265,746	14.2%
	#50(C)	46,806,625	11,582,786	---	11,582,786	35,223,839	25.7%
	#60(SC)	80,212,250	15,218,189	---	15,218,189	64,994,061	19.1%
	#70(NE)	58,636,750	4,717,261	---	4,717,261	53,919,489	8.7%
	#80(EC)	31,641,000	4,953,211	---	4,953,211	26,687,789	16.2%
	#90(SE)	34,348,125	5,683,492	---	5,683,492	28,709,633	16.8%
	STATE	**592,347,500**	**189,347,961**	**---**	**189,347,961**	**402,999,539**	**33.1%**
2005	#10(NW)	70,139,000	9,772,000	0	9,772,000	60,367,000	13.9%
	#20(WC)	49,992,000	26,179,000	17,205,000	43,384,000	6,608,000	86.8%
	#30(SW)	172,039,000	75,642,000	4,440,000	80,082,000	91,957,000	46.5%
	#40(NC)	72,782,000	6,812,000	0	6,812,000	65,970,000	9.4%
	#50(C)	48,815,000	9,253,000	17,760,000	27,013,000	21,802,000	55.3%
	#60(SC)	87,753,000	12,352,000	9,250,000	21,602,000	66,151,000	24.6%
	#70(NE)	74,936,000	4,170,000	2,220,000	6,390,000	68,546,000	8.5%
	#80(EC)	37,161,000	4,510,000	12,950,000	17,460,000	19,701,000	47.0%
	#90(SE)	47,133,000	4,955,000	0	4,955,000	42,178,000	10.5%
	STATE	**660,750,000**	**153,645,000**	**63,825,000**	**217,470,000**	**443,280,000**	**32.9%**
2006	#10(NW)	59,694,000	10,766,000	0	10,766,000	48,928,000	18.0%
	#20(WC)	41,569,000	27,684,000	17,205,000	44,889,000	(3,320,000)	108.0%
	#30(SW)	123,276,000	76,987,000	4,440,000	81,427,000	41,849,000	66.1%
	#40(NC)	52,112,000	6,570,000	14,800,000	21,370,000	30,742,000	41.0%
	#50(C)	34,469,000	9,610,000	17,760,000	27,370,000	7,099,000	79.4%
	#60(SC)	67,770,000	12,547,000	9,250,000	21,797,000	45,973,000	32.2%
	#70(NE)	56,198,000	4,501,000	2,220,000	6,721,000	49,477,000	12.0%
	#80(EC)	24,526,000	4,723,000	12,950,000	17,673,000	6,853,000	72.1%
	#90(SE)	30,386,000	5,287,000	0	5,287,000	25,099,000	17.4%
	STATE	**490,000,000**	**158,675,000**	**78,625,000**	**237,300,000**	**252,700,000**	**48.4%**
2007	#10(NW)	105,510,900	11,012,150	0	11,012,150	94,498,750	10.4%
	#20(WC)	74,348,900	28,300,850	17,205,000	45,505,850	28,843,050	61.2%
	#30(SW)	186,227,300	78,242,900	24,790,000	103,032,900	83,194,400	55.3%
	#40(NC)	73,829,900	6,976,850	14,800,000	21,776,850	52,053,050	29.5%
	#50(C)	53,944,000	10,209,650	17,760,000	27,969,650	25,974,350	51.8%
	#60(SC)	86,246,000	12,394,600	29,600,000	41,994,600	44,251,400	48.7%
	#70(NE)	74,794,000	4,653,900	2,220,000	6,873,900	67,920,100	9.2%
	#80(EC)	35,505,000	4,862,400	12,950,000	17,812,400	17,692,600	50.2%
	#90(SE)	39,595,000	5,487,300	0	5,487,300	34,107,700	13.9%
	STATE	**730,000,000**	**162,140,600**	**119,325,000**	**281,465,600**	**448,534,400**	**38.6%**

Appendix B. Table 3. Maximum Potential DDG Use Versus Kansas Supply (2005-2007)

Year(s)	Kansas CRDs	Maximum DDGs for Cattle On Feed (1,000 lbs.)	Maximum DDGs for Swine & Dairy (1,000 lbs.)	Total Maximum DDG Use (1,000 lbs.)	DDG Production Capacity (1,000 lbs.)	Net Balance of Max DDG Use vs. Supply (1,000 lbs.)	Train Cars = Max DDG Use Net Balance (106.1 tons/car)
2005	#10 (NW)	277,400	37,464	314,864	0	(314,864)	1,484
	#20 (WC)	826,500	44,664	871,164	292,485	(578,679)	2,727
	#30 (SW)	2,589,700	55,384	2,645,084	75,480	(2,569,604)	12,109
	#40 (NC)	129,200	39,384	168,584	0	(168,584)	794
	#50 (C)	260,300	36,024	296,324	301,920	5,596	(26)
	#60 (SC)	391,400	34,904	426,304	157,250	(269,054)	1,268
	#70 (NE)	38,000	39,064	77,064	37,740	(39,324)	185
	#80 (EC)	81,700	35,544	117,244	220,150	102,906	(485)
	#90 (SE)	79,800	36,024	115,824	0	(115,824)	546
	STATE	**4,674,000**	**358,460**	**5,032,460**	**1,085,025**	**(3,947,435)**	**18,602**
2006	#10 (NW)	311,600	37,784	349,384	0	(349,384)	1,646
	#20 (WC)	877,800	45,144	922,944	292,485	(630,459)	2,971
	#30 (SW)	2,631,500	56,184	2,687,684	75,480	(2,612,204)	12,310
	#40 (NC)	127,300	38,744	166,044	251,600	85,556	(403)
	#50 (C)	271,700	36,184	307,884	301,920	(5,964)	28
	#60 (SC)	399,000	34,744	433,744	157,250	(276,494)	1,303
	#70 (NE)	38,000	40,184	78,184	37,740	(40,444)	191
	#80 (EC)	91,200	35,384	126,584	220,150	93,566	(441)
	#90 (SE)	96,900	35,704	132,604	0	(132,604)	625
	STATE	**4,845,000**	**360,060**	**5,205,060**	**1,336,625**	**(3,868,435)**	**18,230**
2007	#10 (NW)	321,100	38,023	359,123	0	(359,123)	1,692
	#20 (WC)	900,600	45,457	946,057	292,485	(653,572)	3,080
	#30 (SW)	2,677,100	56,607	2,733,707	421,430	(2,312,277)	10,897
	#40 (NC)	142,500	38,993	181,493	251,600	70,107	(330)
	#50 (C)	294,500	36,407	330,907	301,920	(29,987)	137
	#60 (SC)	395,200	34,953	430,153	503,200	73,047	(344)
	#70 (NE)	43,700	40,447	84,147	37,740	(46,407)	219
	#80 (EC)	96,900	35,599	132,499	220,150	87,650,800	(413)
	#90 (SE)	106,400	35,922	142,322	0	(142,322)	671
	STATE	**4,978,000**	**362,409**	**5,340,409**	**2,028,525**	**(3,311,884)**	**15,607**

Appendix B. Table 4. Sensitivity of Kansas Net Feedgrain Plus DDG Feed Equivalents Balances to Supply Shortfalls

Year(s)	Kansas CRDs	Total Supply of Feedgrains (bushels)	DDG to Feedgrain Equivalent[1] (equivalent bushels)	Total Feedgrain Use (w/o Exports-Stocks) (bushels)	Net Feedgrain Balance + equiv. DDG Use (w/o Expts-Stks) (bu.)	Sensitivity: Net Balance - 10% less Feedgrains (bu.)	Sensitivity: Net Balance - 33% less Feedgrains (bu.)
2005	#10 (NW)	70,139,000	0	9,772,000	60,367,000	53,353,100	37,221,130
	#20 (WC)	49,992,000	1,740,982	43,384,000	8,348,982	3,349,782	(8,148,378)
	#30 (SW)	172,039,000	449,286	80,082,000	92,406,286	75,202,386	35,633,416
	#40 (NC)	72,782,000	0	6,812,000	65,970,000	58,691,800	41,951,940
	#50 (C)	48,815,000	1,797,143	27,013,000	23,599,143	18,717,643	7,490,193
	#60 (SC)	87,753,000	936,012	21,602,000	67,087,012	58,311,712	38,128,522
	#70 (NE)	74,936,000	224,643	6,390,000	68,770,643	61,277,043	44,041,763
	#80 (EC)	37,161,000	1,310,417	17,460,000	21,011,417	17,295,317	8,748,287
	#90 (SE)	47,133,000	0	4,955,000	42,178,000	37,464,700	26,624,110
	STATE	**660,750,000**	**6,458,482**	**217,470,000**	**449,738,482**	**383,663,482**	**231,690,982**
2006	#10 (NW)	59,694,000	0	10,766,000	48,928,000	42,958,600	29,228,980
	#20 (WC)	41,569,000	1,740,982	44,889,000	(1,579,018)	(5,735,918)	(15,296,788)
	#30 (SW)	123,276,000	449,286	81,427,000	42,298,286	29,970,686	1,617,206
	#40 (NC)	52,112,000	1,497,619	21,370,000	32,239,619	27,028,419	15,042,659
	#50 (C)	34,469,000	1,797,143	27,370,000	8,896,143	5,449,243	(2,478,627)
	#60 (SC)	67,770,000	936,012	21,797,000	46,909,012	40,132,012	24,544,912
	#70 (NE)	56,198,000	224,643	6,721,000	49,701,643	44,081,843	31,156,303
	#80 (EC)	24,526,000	1,310,417	17,673,000	8,163,417	5,710,817	69,837
	#90 (SE)	30,386,000	0	5,287,000	25,099,000	22,060,400	15,071,620
	STATE	**490,000,000**	**7,956,101**	**237,300,000**	**260,656,101**	**211,656,101**	**98,956,101**
2007	#10 (NW)	105,510,900	0	11,012,150	94,498,750	83,947,660	59,680,153
	#20 (WC)	74,348,900	1,740,982	45,505,850	30,584,032	23,149,142	6,048,895
	#30 (SW)	186,227,300	2,508,512	103,032,900	85,702,912	67,080,182	24,247,903
	#40 (NC)	73,829,900	1,497,619	21,776,850	53,550,669	46,167,679	29,186,802
	#50 (C)	53,944,000	1,797,143	27,969,650	27,771,493	22,377,093	9,969,973
	#60 (SC)	86,246,000	2,995,238	41,994,600	47,246,638	38,622,038	18,785,458
	#70 (NE)	74,794,000	224,643	6,873,900	68,144,743	60,665,343	43,462,723
	#80 (EC)	35,505,000	1,310,417	17,812,400	19,003,017	15,452,517	7,286,367
	#90 (SE)	39,595,000	0	5,487,300	34,107,700	30,148,200	21,041,350
	STATE	**730,000,000**	**12,074,554**	**281,465,600**	**460,608,954**	**387,608,954**	**219,708,954**

Footnote 1: Assuming that DDGS have 1/3 the nutritional value of feedgrains in livestock feed rations.

Appendix C

Appendix C. Table 1. Description of Kansas Corn Yield Model Variables

Variable	Description	Mean	Stand Dev	Min	Max
Y_{it}	Average District Corn Yield (bu/acre)	82.33	30.86	20.45	164.21
$APRP_{it}$	April Precipitation (inches)	2.62	1.55	0.18	12.05
$MAYP_{it}$	May Precipitation (inches)	4.17	2.15	0.41	11.77
$JUNP_{it}$	June Precipitation (inches)	4.03	2.09	0.37	16.29
$JULP_{it}$	July Precipitation (inches)	3.51	2.31	0.25	17.93
$AUGP_{it}$	August Precipitation (inches)	3.35	1.86	0.05	9.19
$APRT_{it}$	Monthly Average Daily Maximum Temperature for April (degrees Fahrenheit)	53.79	3.65	44.40	63.80
$MAYT_{it}$	Monthly Average Daily Maximum Temperature for May (degrees Fahrenheit)	63.41	3.12	52.20	70.40
$JUNT_{it}$	Monthly Average Daily Maximum Temperature for June (degrees Fahrenheit)	73.14	2.89	64.60	80.10
$JULT_{it}$	Monthly Average Daily Maximum Temperature for July (degrees Fahrenheit)	78.89	2.55	71.70	87.80
$AUGT_{it}$	Monthly Average Daily Maximum Temperature for August (degrees Fahrenheit)	77.00	3.14	68.40	85.10
e_{it}	Error term	n/a	n/a	n/a	n/a

Appendix C. Table 2. Kansas Non-irrigated Corn Yield Model

Variable	Coefficient		Std. Err.	T-Stat	P-values
Intercept	0.587		12.814	0.050	0.963
$APRP_{it}$	0.105	*	0.027	3.880	0.000
$MAYP_{it}$	0.063	**	0.027	2.320	0.021
$JUNP_{it}$	0.053	**	0.023	2.290	0.023
$JULP_{it}$	0.208	*	0.019	11.170	0.000
$AUGP_{it}$	-0.026		0.036	-0.720	0.474
$APRT_{it}$	-0.316	*	0.105	-3.000	0.003
$MAYT_{it}$	0.291	***	0.168	1.730	0.085
$JUNT_{it}$	0.521	**	0.239	2.190	0.030
$JULT_{it}$	-0.030		0.278	-0.110	0.915
$AUGT_{it}$	-0.403	***	0.220	-1.830	0.068
$(APRP_{it})^2$	-0.007	**	0.003	-2.270	0.024
$(MAYP_{it})^2$	-0.003		0.002	-1.140	0.256
$(JUNP_{it})^2$	-0.002		0.002	-0.880	0.379
$(JULP_{it})^2$	-0.012	*	0.001	-8.670	0.000
$(AUGP_{it})^2$	0.005		0.004	1.320	0.189
$(APRT_{it})^2$	0.003	*	0.001	2.910	0.004
$(MAYT_{it})^2$	-0.002	***	0.001	-1.660	0.098
$(JUNT_{it})^2$	-0.004	**	0.002	-2.150	0.033
$(JULT_{it})^2$	0.000		0.002	0.100	0.922
$(AUGT_{it})^2$	0.002	***	0.001	1.760	0.080

$R^2 = 0.5525$ n = 322

* Significance at 1% level; ** Significance at 5% level; *** Significance at 10% level

Appendix D.

Kansas Grain Handlers Marketing Survey (Condensed Sample)

1. Please classify your operation in one of the following categories. *(please check one)*

- ☐ Country elevator
- ☐ Terminal elevator
- ☐ Grain dealer w. bonded warehouse storage capacity
- ☐ Grain dealer with no licensed warehouse storage capacity
- ☐ Other *(specify)* ___________________

2. What is the distance from your facility to the nearest ethanol plant? *(please check one)*

0-10 miles ______ 11-20 miles_______ 21-30 miles_______ 31-40 miles_______
41-50 miles______ 51-60 miles_______ more than 60 miles_______

3. Elevator Capacity: What is your elevator's the grain storage & railroad car handling capacity?

Upright grain storage? ____________________ (Bu.)
Flat grain storage? ____________________ (Bu.)
Railroad car handling capacity? ____________________ (# of Rail cars)

4. Do you regularly store grain on the ground for temporary storage? Yes___No___;

If Yes, % of years grain stored on ground _____%; Number of Bushels ____________(Bu.)

5. Do you have plans to expand your grain holding capacity? Yes_____ No_____;

If Yes, by how much do you plan to expand? ____________________ (Bu.)

6. What was the approximate volume of feedgrain movement to and from your facility for the 2006 market year of September 1, 2006 through August 31, 2007?

	Corn	**Grain Sorghum**
Bushels Received / Purchased	Bu.	Bu.
% of total Bushels Shipped / Processed	%	%
Bushels Shipped / Processed	Bu.	Bu.

7. Ethanol Co-Products: Are you now handling ethanol co-products such as DGS/WDGS? Yes ____ No____

If No, do you foresee handling ethanol co-products within 5 years)? Yes ____ No____

8. What was the volume of ethanol co-products handled, brokered, mixed, or processed from September 1, 2006 through August 31, 2007? (Ethanol co-products include dried or wet distillers grains, corn gluten feed or meal, brewers grains, condensed distillers solubles, etc.)

Type of Co-Product	Volume of co-products handled (tons)	Average One-way Miles from source of co-products	Maximum One-way Miles from source of co-products
DDGS	___________tons	_________miles (avg.)	________miles (max.)
WDGS	___________tons	_________miles (avg.)	________miles (max.)
Other: ____________	___________units	_________miles (avg.)	________miles (max.)
Other: ____________	___________units	_________miles (avg.)	________miles (max.)

9. <u>Non-Grain Sales TO Ethanol Plants</u>: What type and dollar volume of <u>non-grain products</u> did you sell TO ethanol plants last year?

Product	**Quantity / Volume**
Urea	
Ammonium Nitrate	
Other products…. Please specify	

10. <u>Rail Access</u>: Does your elevator have access to railroad services? Yes_____ No_____;

If Yes, which type of Rail Service Provider do you have access to? *(please check one)*

- Class I Railroad (Burlington Northern Sante Fe (BNSF) or Union Pacific (UP) Railroads):_______
- Class III Railroad (Other Kansas short line rail service providers): _______

If Yes, do you think you will continue to have rail service in five years? Yes____ No____;

11. <u>How Grain Was Shipped FROM Your Elevator</u>: In what proportion (%) was grain shipped FROM your grain elevator facility in calendar year 2007?

Shipped out by Truck: _____%; Shipped out by Rail:_____%; By Other Means:_____%

12. <u>Rail Shipments by Type of Grain</u>: Of your firm's rail shipments, what is the typical number of rail cars per shipment for the different types of grain you handle?

		Typical Number of Rail Cars per Shipment				
	Not Applicable	1 – 24 railcars	25 – 49 railcars	50 – 74 railcars	75 – 99 railcars	100+ railcars
Corn						
Grain Sorghum						
Wheat						
Soybeans						

13. <u>Grain Basis Influences</u>: What factors have played the greatest influence the local basis for corn and grain sorghum over the last 10 years?

____

____

14. <u>Ethanol Plant Influence on Local Grain Basis</u>: By what amount ($/Bu.) has the recent development of grain ethanol processing affected your local cash market basis for feedgrains? *(please check appropriate category)*

	No Effect	Less $0.01-0.05 / bushel	Less $0.06-0.10 / bushel	Less $0.11-0.15 / bushel	Less $0.16-0.20 / bushel	More than $0.20 / bushel
Corn						
Grain Sorghum						

15. <u>Ethanol Plant Influence on Local Crop Acreage</u>: Has ethanol plant development affected the acreage of different crops grown in your local area? (please check appropriate box for each crop)

Crops	Crop Acreage Trends from Ethanol		
	Less Acres	No Change	More Acres
Corn			
Grain Sorghum			
Wheat			
Soybeans			

16. <u>Quantity of Grain Sold from Elevator Directly to Ethanol Plants</u>: What volume of feedgrains were sold directly to ethanol plants from your grain elevator during 2007?

	Corn	Grain Sorghum	Other Grains
Volume of Grain Sold from Elevator Directly to Ethanol Plants	___________Bu.	___________Bu.	___________Bu.

17. <u>Proportion of Grain Sold from Local Area Directly to Ethanol Plants</u>: What proportion (%) of locally produced feedgrains were sold directly to ethanol plants during 2007?

	Corn	Grain Sorghum	Other Grains
% of Local Feedgrain Production Sold Directly to Ethanol Plants	___________%	___________%	___________%