An Optimization Model of the Ethanol Distillers Grain Market in Nebraska

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Abstract: The rapid expansion of the ethanol industry brings forth a number of questions about its immediate future. Chief among these is the issue of the sustainable level of ethanol production. Will the current level of rapid growth continue, will it slow and find a sustainable level of production, or will the industry experience the "overshoot and collapse" pattern made famous by the Limits to Growth? This paper examines the Nebraska situation regarding the potential constraint arising from the limitations of the transportation of wet distillers grains. We created a linear program model to identify the distribution of feedlots relative to existing and planned ethanol facilities.

Introduction

The expansion of corn based ethanol production over the past seven years is nothing short of spectacular – a modern day version of the gold rush. In January 2000, there were 54 U.S. plants with production capacity of 1.7487 billion gallons per year. As of June 2007, there were 119 ethanol plants with a production capacity of 6.1834 billion gallons. Additionally, there are 86 plants under construction or expansion which will add another 6.3799 billion gallons capacity in the near future (Renewable Fuels Association, 2007). The expansion was sparked by the increase in petroleum prices and fanned by government policy. The Renewable Fuels Standard (RFS) included in the Energy Policy Act of 2005 called for the production of 4 billion gallons of ethanol in 2006, with increased production capacity up to 7.5 billion gallons by 2012, an average annual growth rate of 11%. The industry surpassed the 2006 goal, and is on track to exceed the 2012 goal in 2007. Government policy is an important driver - the Federal subsidy of $0.51 per gallon of ethanol was established when crude oil was less than $30 per barrel. The subsidy was necessary to make ethanol profitable. However, with crude oil prices rising into the $70 per barrel range, ethanol has shifted from being just profitable to being highly profitable – stimulating major investment (Hurt, Tyner, & Doering, 2007). . In 2007, the pace of ethanol expansion slowed noticeably due to several factors. The moderation reflected declining profit margins as ethanol prices (F.O.B. Omaha) dropped from $3.58 per gallon in June, 2006 to $1.79 in October, 2007 (NEO, 2007). Higher input costs with corn rising from $2.00 per bushel in the 2005-06 crop year to $3.95 per bushel in the 2007-08 crop year – nearly a 100% increase (USDA, 2007). Compounding the production issues was the general turmoil in the financial markets that made acquiring credit more difficult.

The rapid expansion is particularly evident in states like Nebraska, which currently ranks second in ethanol production. As of the summer of 2007, there are 17 operating plants in the state with approximately one billion gallons capacity. There are 10 plants under construction, roughly doubling capacity in the near future. On a slightly longer time horizon, there are another 9 plants at various points in the permit process and 22 plants in the proposed category. If all the permitted and proposed plants are constructed, Nebraska's production capacity will rise to 5.1 billion gallons (NEO, 2007).

The rapid expansion brings forth a number of questions about the immediate future of the ethanol industry. Chief among these questions is the issue of the sustainable level of ethanol production. Will the current level of rapid growth continue, will it slow and find a sustainable level of production, or will the industry experience the "overshoot and collapse" pattern made famous by the *Limits to Growth*? (Meadows, 1974) This paper examines the Nebraska situation in attempt to identify the limits to ethanol expansion.

As with any productive process, there are a number of possible market constraints or resource availability limits that could individually or jointly curtail the continued ethanol expansion. For example, one possible market limitation is that producers would meet or exceed the potential demand for ethanol. The availability of corn or the price of corn are potential limitations. The market for distillers grains and other byproducts may prove to be the limiting factor.

Production Process

To understand the possible limitations, it is important to understand the fundamental process of ethanol production. There are two basic types of ethanol production plants - wet mill and dry mill. The wet mill process soaks the grain (corn is the most common) then splits it into its components. The germ of the corn is used to produce corn oil and the starch produces the ethanol. The dry mill process grinds the corn into flour using hammer mills. This flour is fermented to convert the starch to ethanol, with the remainder either sold as wet distillers grains (WDGS) or dried and sold as dried distillers grains with soluble (DDGS). While there is a greater range of valuable products produced by the wet mill process, the cost of building a wet mill facility is greater than that of a dry mill plant.

In the more common dry mill process, each 56 pound bushel of corn produces approximately 2.7 gallons of ethanol, 17 lbs of distillers grains, and 18 lbs of carbon dioxide. The ethanol is usually shipped in tanks by train, truck or barge rather than by pipeline because it has a tendency to absorb the water and impurities commonly found in pipelines. It is mixed directly with gasoline in the tanker trucks that deliver fuel to the gas stations.(amber waves) The distillers grain is desirable livestock feed, particularly for beef cattle. Wet distillers grain is one third water, so is generally used within three days in the summer or six days in the winter to avoid spoilage. Because of transportation cost it is generally fed to cattle within fifty miles of the plant. Dried distillers grain has a much longer shelf life and is transported around the world. However, the energy required to dry the distillers grain is substantial – nearly doubling the amount of energy used by the ethanol plant. The critical energy cost in ethanol production is the price of natural gas, which is used both to heat the mashed corn to produce ethanol and to dry the distillers grains to produce DDGS. Natural gas typically accounts for about 10 percent of operating expenses to produce ethanol and wet distillers grains (Coltrain, 2004).

Large quantities of carbon dioxide are produced as a co-product during ethanol production. A 100 million gallon plant will produce 330 tons of carbon dioxide annually. While some plants capture the carbon dioxide for industrial uses, medicinal gases, or dry ice production, many simply vent the gas. However, the profitability of capturing and marketing the carbon dioxide is typically low. Only an easily accessible market warrants installing equipment to capture the carbon dioxide that can be produced. Even with an accessible market, the profitability of selling carbon dioxide is minimal because of the cost of installing specialized equipment which runs in the 8 - 12 million dollar range. To illustrate, a 30 million gallons per year ethanol plant marketing CO_2 would normally receive about $500,000 of additional income each year, far below the cost of capital for the specialized equipment (Coltrain, 2004).

Availability of corn

As illustrated by Figure 1, ethanol is claiming an increasing proportion of the U.S. corn crop. However, ethanol use remains modest relative to other uses and to exports. Softening the impact of increasing ethanol usage is the projected increase in corn acreage (Figure 2).

Figure 1

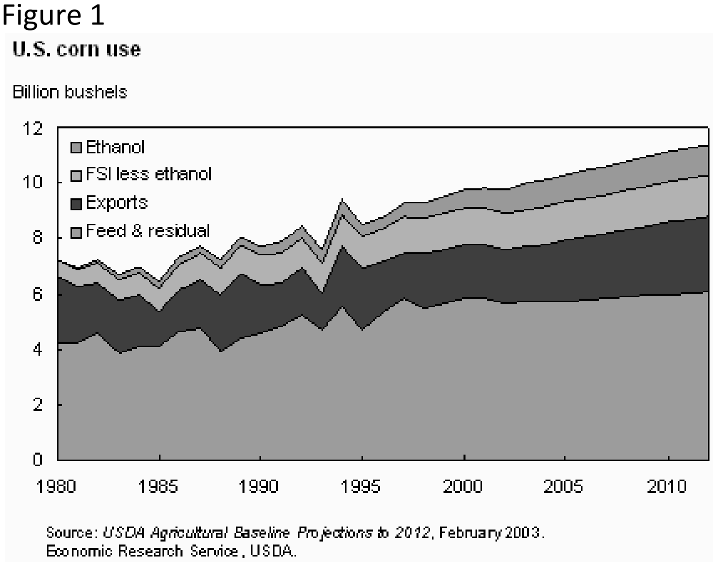
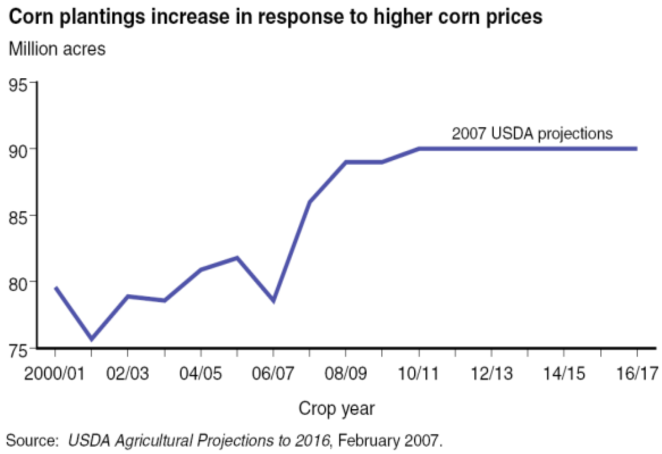


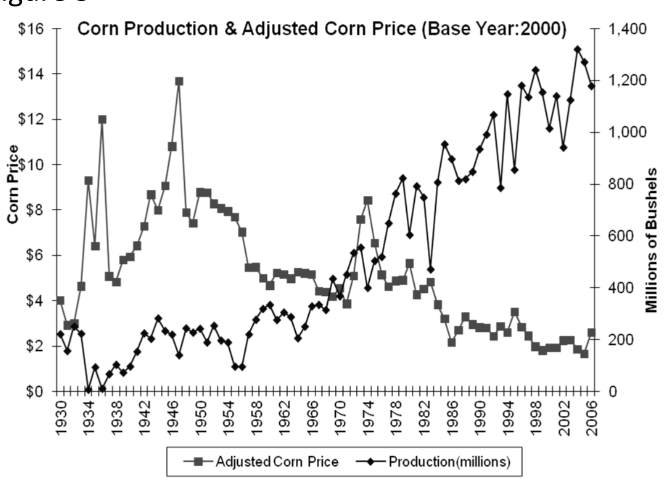
Figure 2



Price of corn

The nominal increase in corn price is somewhat misleading. As illustrated by Figure 3, the inflation adjusted corn price trends downward over time. The recent price spike is problematic in the short-run. According to a Purdue University study, when a plant can buy corn at less than $4.82 per bushel, the owners will get a higher return than 12% and/or a quicker payback than 15 years. The report also notes that the capital cost component of ethanol production cost is about 30 cents per gallon, or 80 cents per bushel. This means that existing plants with capital costs already recovered could potentially pay 80 cents more per bushel or about $5.60 (Hurt, Tyner, & Doering, 2007).

Figure 3



Cattle Availability

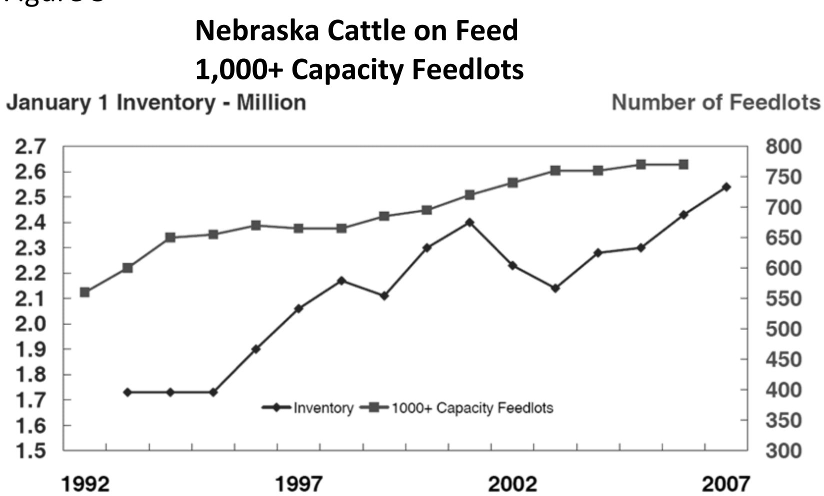
Distillers grain is a marketable byproduct of ethanol production. A 100 million gallon capacity plant will produce sufficient distillers grain to feed 133,000 cattle. Wet and dry distillers grains have different characteristics which impact their use. Wet distillers grains is the more desirable cattle feed, but its high moisture content gives it a limited shelf life. Transporting wet distillers grain long distances is problematic because of the weight of the water. Generally, wet distillers grain is fed to cattle within 50 miles of the ethanol plant.

Figure 4
Distillers Grains Characteristics

Wet Distillers Grains (WDGS)	Dry Distillers Grains (DDGS)
60-70% moisture	10% moisture
Desirable cattle feed	Multiple uses
Short shelf life in warm weather	Less palatable for cattle
Messy to transport	Long shelf life
Transport 50 miles or less	Easily transportable
Energy savings	Transport worldwide
	Considerable energy used in drying

As illustrated by Figure 5, Nebraska has sufficient cattle on feed to use considerable amounts of distillers grain. Over time, Nebraska cattle on feed inventory has increased and the number of large feedlots has also increased. Larger feed lots are compatible with increased use of wet distillers grain because they can use large quantities of feed in a short period.

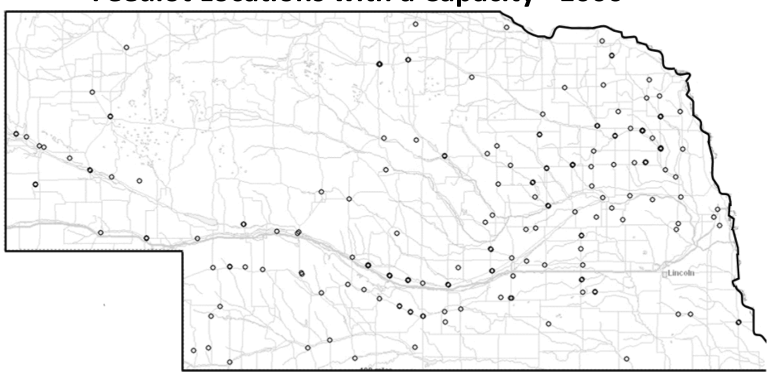
Figure 5



Examining Nebraska feedlots, one finds a pattern of concentration through the eastern third of the state and along the Platte River valley.

Figure 6

Feedlot Locations with a Capacity +1000

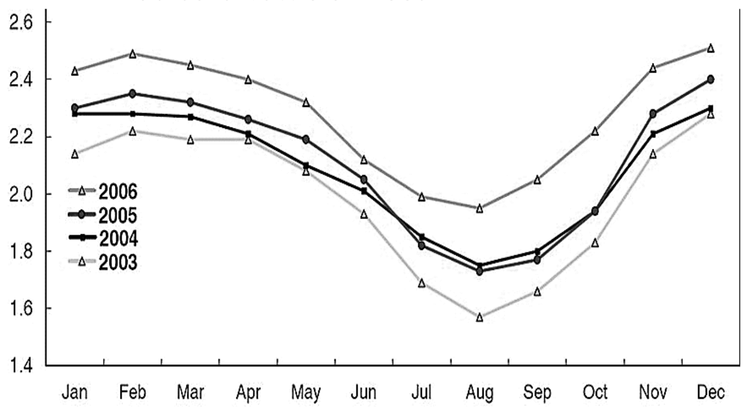


Sources: Nebraska Department of Environmental Quality, May 2007
Beef Spotter – The Feedlot Atlas, 2007

There is a pronounced seasonal pattern in cattle on feed inventories. Inventories tend to be lowest during the summer months. This is problematic because the shelf life of wet distillers grain is shortest in hot weather. Figure 7, shows the year-to-year growth and monthly seasonal pattern.

Figure 7

Nebraska Cattle on Feed

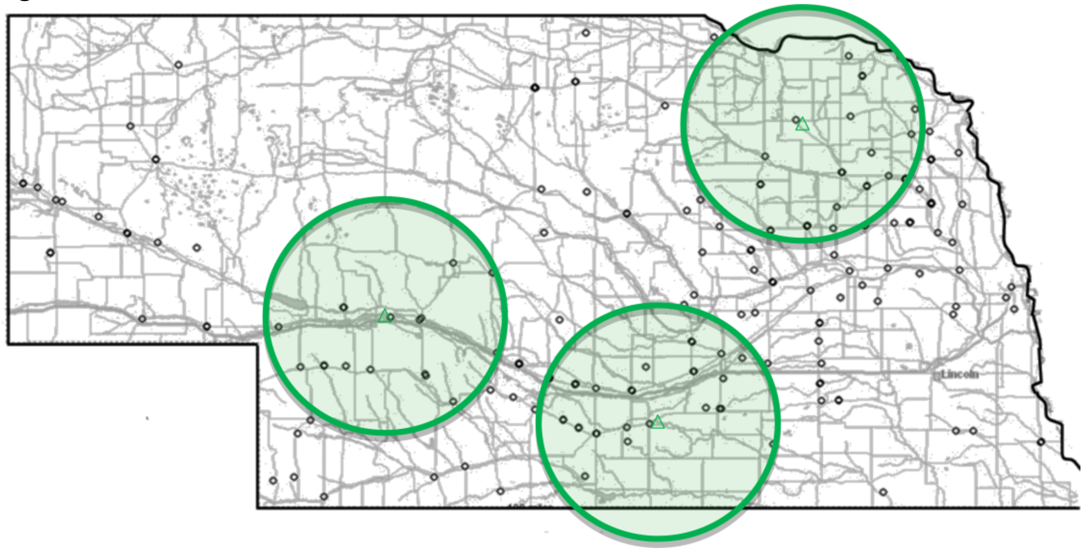


Source: USDA NASS Nebraska Field Office - January 26, 2007

Wet Distillers Grains Market

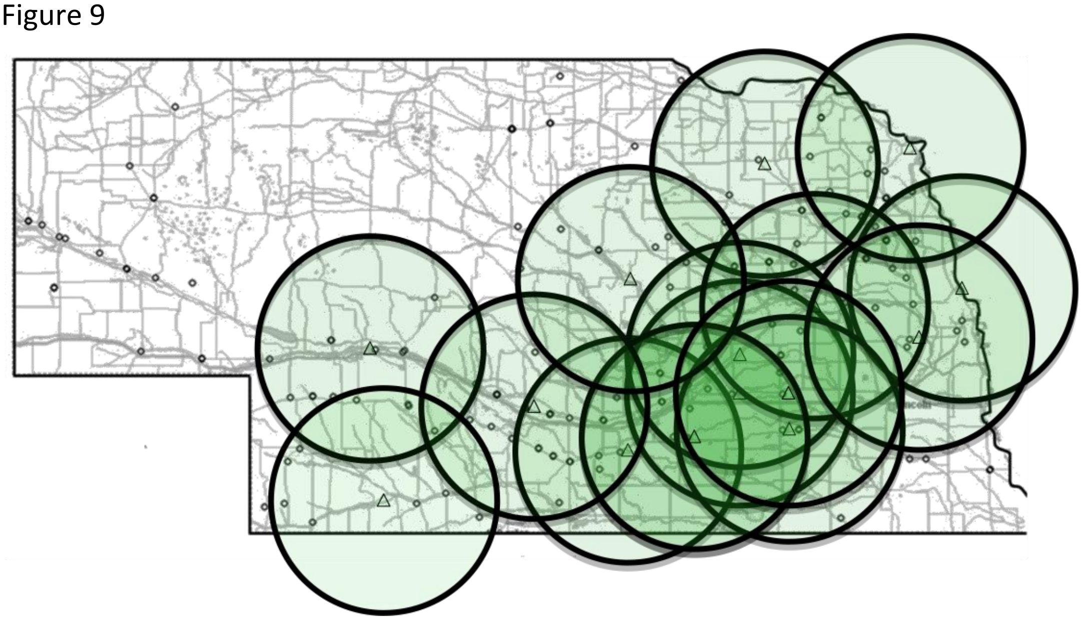
Early ethanol plants had the advantage of selling wet distillers grains in virgin markets. High transportation costs effectively limit transportation to fifty miles or less. Thus, as illustrated by Figure 8, early plants were not directly competing with one another on selling wet distillers grains to local feedlots. Each circle represents the fifty mile radius for three early operational plants.

Figure 8



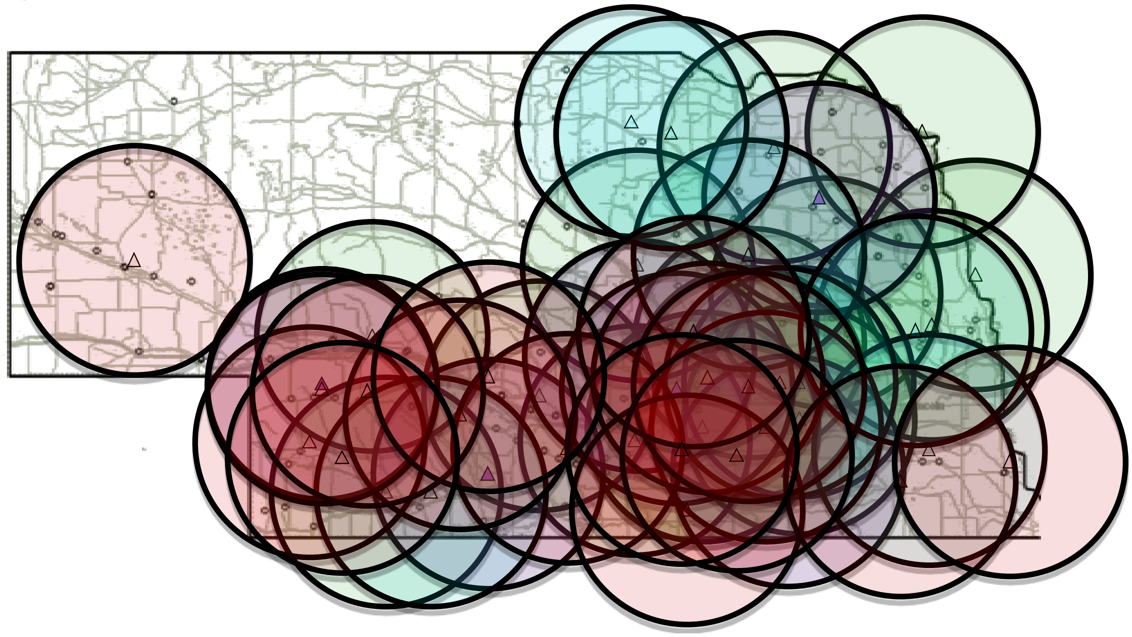
By May of 2007 the distillers grains market in Nebraska had changed. With sixteen operational ethanol plants, feedlots in the central and eastern parts of the state had multiple potential sources of WDGS. Figure 9 shows the overlapping market areas for each of the operating plants in May, 2007.

Figure 9



Compounding the issue, multiple additional plants are in various stages of construction, permitting or initial proposal. If all of the permitted and proposed plants come online by 2015, the WDGS market will be over saturated across nearly all the state. Figure 10 presents the situation as it may exist in 2015.

Figure 10



Linear Programming Transportation Model: The purpose of the LP model is to identify the proportion of shipped dry distillers grains and wet distillers grains in a best case scenario. Assumptions include: cattle on feed are fed at 45% WDGS, WDGS are not shipped beyond 50 miles, all new construction is dry mill process, and the total cattle on feed increases 2.5% annually. The model minimizes the transportation cost of WDGS to feedlots in the critical month of July, when cattle on feed is at the lowest level of the year. In the model, $C_{i,j}$ represents the distance between ethanol plant *i* and feedlot *j*, $X_{i,j}$ represents the quantity of WDGS shipped between *i* and *j*, S_i represents the total supply of WDGS from ethanol plant *i*, and d_j represents the demand for WDGS by feedlot *j*.

$$Min \sum_{i=1}^{m} \sum_{j=1}^{n} C_{i,j} X_{i,j}$$

Subject to

$$\sum_{j=1}^{n} X_{i,j} = S_i \qquad i = 1,2, \ldots. m \;\; Ethanol\ Plants$$

$$j = 1,2, \ldots n \;\; Feed\ Lots$$

$$\sum_{i=1}^{m} X_{i,j} \leq d_j \qquad \text{for all } i \text{ and } j$$

Model Characteristics

Known feedlots: 289		Constraints:	320
Ethanol plants: 46		Variables:	12,559
		Non-zeros:	25,163

Cattle on feed in July (2.5% annual growth rate)

In 2007: 1,910,000
In 2009: 2,007,000
In 2012: 2,161,000
In 2015: 2,327,000

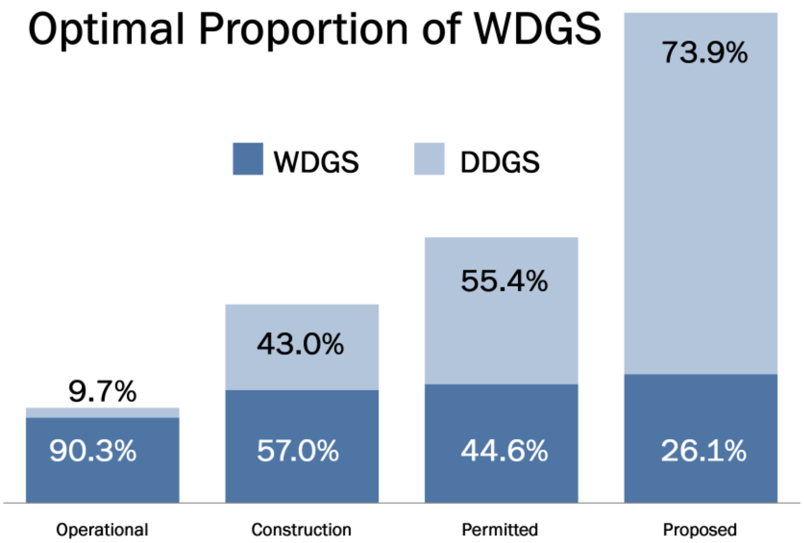
A sample of the mileage table used in the model is illustrated in Figure 11.

Figure 11

			Lexington	Mead	Minden	Ord
	Latitude		40.78	41.23	40.50	41.60
		Longtitude	-99.74	-96.49	-98.95	-98.93
Olsencattleco	40.51	-98.90	48	136	2	76
Olson Farms, Inc.	41.18	-101.03	73	236	119	113
Oneida Farms Pt	40.36	-99.17	42	153	15	87
Oppliger Feedyard	40.85	-101.18	76	246	120	128
Ortmeier Farms	41.68	-96.88	162	37	136	106
Oshkoshfeedyard	41.62	-102.33	147	304	193	176
Ottlivestockllc	41.95	-96.90	168	55	146	107
PandorfLandandcattle	41.19	-100.07	33	186	76	66
Panhandle Feeders, Inc.	42.05	-103.95	236	390	281	261
Paradisefeedersstanton	41.87	-97.19	152	58	132	91
Paul Johnson & Sons,	40.52	-99.64	19	172	37	84
Paul Ridder Feedlots	41.87	-96.74	173	46	149	114
Paulsen Farms, Inc.	41.13	-99.66	25	166	58	50
Pester Farms	41.89	-103.47	208	364	254	235
Phelps County Feeders	40.45	-99.36	30	160	22	83

Model Results: While optimally the currently operational plants would only need to dry 9.7% of distillers grains, by 2015 if the proposed plants are built, 73.9% of the distillers grains would need drying.

Figure 12



Conclusion

Given that drying distillers grains increases energy costs by 50% for ethanol plants, the trend toward increasing drying will present a significant cost challenge in the future. Communities attempting to attract or assist ethanol plant development should be mindful of the changing nature of the distillers grain market.

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