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Economic Model Evaluation of Largest Sugar-beetProduction in U.S. States of North Dakota and Minnesota

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ABSTRACT *: A comprehensive economic model of sugar-beet growing, transportation, and processing has been developed for the Red River Valley of North Dakota and Minnesota in the U.S. to analyze the critical cost attributes and parameters. A methodology for the use of baseline data for production costs of sugar-beet farms, transportation and sugar-beet processing costs at the factory level along with criteria that could be used as means of measuring benefits realized by the partners/growers is developed. The main purpose of the proposed economic analysis is to incorporate changes in critical attributes directly as a result of forecast model(s) using remote senor data (NDVI), in-situ sensor data (plant height), etc. in order to maximize yield and profits, and to minimize associated costs at each phase of production.*

Keywords-*Economic Model, Sugar-beet, American Crystal Sugar Company, NDVI, In-Situ Sensor, Yield Prediction*

I. INTRODUCTION

Sugar-beet production in the Red River Valley of Minnesota and North Dakota is a Co-op operation managed by American Crystal Sugar Company (ACSC). As the largest sugar-beet producer in the United States, which is owned by about 2800 shareholders who raise nearly 40% of the nation's sugar-beet acreage and produces about 17% of America's sugar, ACSC operates five sugar processing facilities in Crookston, East Grand Forks, and Moorhead, Minnesota; Drayton and Hillsboro, North Dakota; and in Sidney, Montana, (under the name Sidney Sugars Incorporated). The company's technical services center and corporate headquarters are also located in Moorhead, MN [1].

In Fiscal Year 2012, shareholders received an average gross beet payment of $58.67 per ton, which translated to $1,212 on a per acre basis. These payments were the second and fourth highest, respectively in ACSC's history. Factories produced 26 million hundredweight of sugar and 602,000 tons of agri-products from September 8, 2011 to May 5, 2012.

In this article we considered only the five locations in Red River Valley. They are located at Crookston, East Grand Forks, and Moorhead in Minnesota; and Drayton and Hillsboro in North Dakota. The sugar beet producing farms are located in both Minnesota and North Dakota in the Red River Valley. Counties and facility locations are shown in Figure 1 [2].

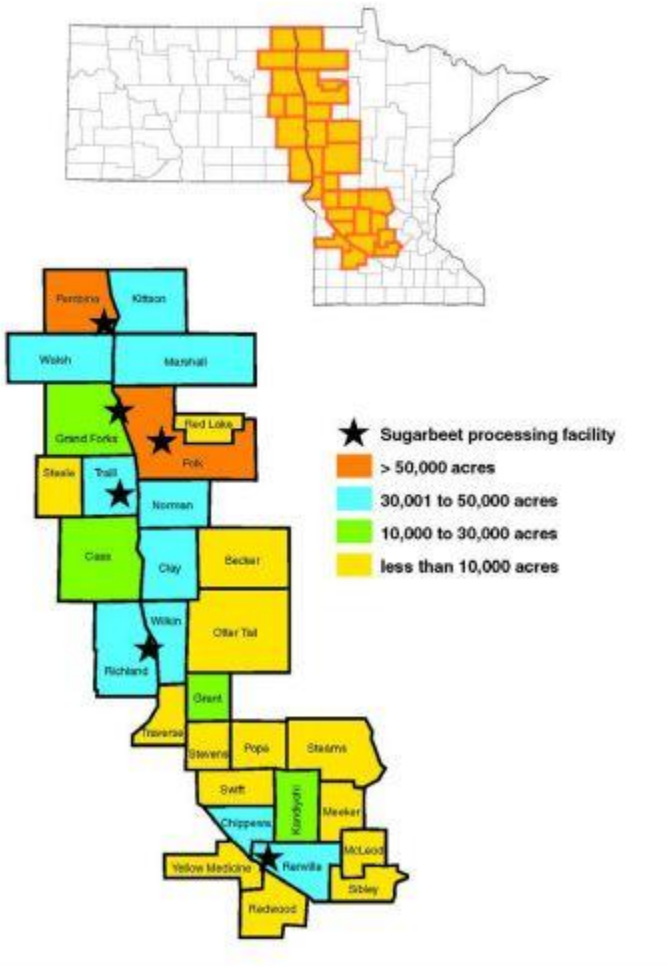

Figure 1 : Sugarbeet production: Counties and Facilities.

The cost associated with the transportation is used in the economic analysis. There are a total of 10 million plantable acres for all crops in the Red River Valley. In 2011, ultimately 452,000 acres were planted with the last acres seeded on June 20. Pre-pile harvest began on September 6 and was followed by full stockpile harvest on October 1. The 2011 crop averaged 20.7 tons per acre with 18.0 percent sugar content. Total tons delivered equaled 9.2 million from 443,000 acres.

The sugar-beet crop is regulated by the ACSC and the shareholders based on storage and processing capacity. For each share of stock members can grow 0.88 acres (0.88 acres/share of ACSC). ACSC employs 24 agronomists who travel to farm, to work with growers, and to collect data. The boundaries of the growing region are from South of Kent, MN to the Canadian border and from east to west in the Red River Valley.

Smit et al., [3] studied tactical level decisions related to growing sugar-beet. They described a method of allocating fixed costs to crops in the cropping plan and included in PIEteR, a bio-economic model for sugar-beet growing. Quota regulations restrict the amount of sugar-beet which can be delivered for the full quota price. When the deliveries are smaller than the quota over a number of years, the quota will be reduced. However, when the deliveries are larger than quota over a number of years, the quota will not be enlarged. They developed a module in PIEteR to compare the marginal returns and the costs of an increase of the area by one ha. They calculated marginal changes and showed these calculations cannot easily be extended to more significant changes. Seed, ware potato, and sugar-beet had the highest returns above allocated variable costs, but when allocated fixed costs were also taken into account, sugar-beet appeared to be more profitable than seed potato.

Ebenezer et al., [4] investigated the feasibility of integrating an ethanol producing plant into an existing sugar processing plant that uses sugar-beet pulp (SBP) as feedstock. They evaluated the feasibility of using SBP as the feedstock in an existing sugar processing plant to ethanol from an economic standpoint. The sugar-beet industry already has many built in production advantages that favor the production of high performance fuels at existing sugar-beet processing plants. First, there are large quantities of SBP already concentrated with no additional transportation cost. Second, energy consumption would be minimal. Flannery et al., [5] examined the predicted costs-benefit analysis of five hypothetical GM crops cultivated in Ireland. The cropping regimes of the four listed crops were compared with equivalent, hypothetical GM scenarios. All figures used were based on crop production data for Ireland and include variable and some element of fixed costs: materials (seed, fertilizers, herbicides, fungicides, insecticides, growth regulators), machinery hire (plowing, tilling, sowing, spraying, fertilizer spreading, harvesting), and miscellaneous costs (interest and transport). They reported that the economic performance of the technology varies significantly between crops and traits. When disease pressure and/or weed concentration is high, it is predicted that specific GM crops will economically outperform conventional crops, based on the cost of chemicals and their application.

Bangsund et al., [2] provided expenditure information by sugar-beet processing and marketing cooperatives. They estimated economic impacts using input-output analysis for production in Minnesota and North Dakota entities in fiscal 2011. Direct economic impacts from sugar-beet production (i.e., production outlays and producer returns) were estimated using cost-of-production budgets and payments to sugar-beet growers, as reported by the cooperatives.

Brookes and Blume [6] explored the potential economic and environmental impacts/benefits of using current commercialized crop biotechnology in Ukraine. They summarized the potential impacts of each trait and crop combination. In almost all cases, the adoption of GM technology is likely to result in a net increase in the levels of profitability for adopting farmers. They examined both the farm level and the national (aggregated) level impacts. The environmental impacts examined were changes in pesticide use and impacts on greenhouse gas (carbon) emissions. They also examined the following crop and trait issues: soybeans, maize, oilseed rape/canola and sugar-beet: (HT), where Maize: insect resistance (IR: targeting ECB and corn rootworm pests).

Adenäuer and Heckelei [7] examined two alternative behavioral models, expected profit maximization and utility maximization, with respect to their ability to contribute to an explanation of observed supply behavior and consequently for a more realistic simulation response to policy changes than previous approaches. Their analysis showed how much two alternative behavioral models can contribute to explain observed sugar production. Yield uncertainty plays an important role under the framework of production quotas since a low yield can lead to considerable income losses if production quotas are not filled. Despite considerable differences between countries and farms, a significant amount of C-sugar production cannot be explained by these models.

Lzarus [8] reported enterprise budgets with detailed estimates of the costs and returns expected for traditional food and feed crops (corn grain, soybeans, spring wheat, sugar-beets, and alfalfa hay) as well as potential energy crops (grassland crops, hybrid poplar trees, willow trees, and corn stover) in Minnesota. The energy crop production costs are intended to include delivery to the final processing plant, so transportation costs and storage losses are considered. Load size is a critical variable, but is highly speculative at this point given that large volume biomass logistics systems are still under development. The maximum load size may be constrained by either weight or volume, depending on the density of the material. Newcomb et al., [9] analyzed the effectiveness of utilizing satellite images in increasing crop yield and quality. The objectives of their research were to 1) improve yield and quality of crops following sugar-beet in rotation; 2) improve sugar-beet quality following rotations on fields, which have been cycled utilizing precision farming methods; 3) reduce grower production costs; and 4) enhance protection of soil and water resources.

Labarta et al., [10] mentioned gross revenue can be stabilized through crop diversification; therefore, farmers would have another reason to adopt longer crop rotations with legumes. Bârsan and Luca [11] analyzed the economic efficiency of the irrigation of the sugar-beet crops cultivated with the aim of obtaining bioethanol. Mukhwana [12] investigated soil processes and economic factors defining agricultural sustainability in dry-land winter wheat and irrigated sugar-beet cropping systems. Their objectives were to 1) determine how soil organic matter pools, microbial populations and diversity and profitability are impacted by diversified dryland winter wheat cropping systems; and 2) determine how soil organic matter pools, microbial populations and diversity and profitability are impacted by alternative irrigated sugar-beet crop rotations and irrigation methods. They mentioned the need for further research to make more conclusive statements about the relative economic performance of various sugar-beet systems. This is because it is entirely possible that systems with the highest gross revenue also have the highest production costs, and potentially even negative net revenue.

El Benni and Finger [13] applied variance decomposition approach using data to quantify the direct and indirect effects of yields, prices and costs on net revenue variability at the farm level. Furthermore, they investigated relevance of different risk sources across crops and the influence of farm characteristics on their risk profile. The results show that costs play only a minor role in determining income variability, but price and yield risks are of outmost importance and very crop specific. May [14] developed a multivariate model, that considers economic and social-psychological variables to explain farmers' behavior to study exclusively farmers' cropping decisions. The model can be used to graphically identify behavioral patterns across farmers. The aim was to predict the crop allocations made by sugar-beet growers in response to the Sugar Regime reform introduced in 20th February 2006. The multivariate model integrates a number of different approaches into a single framework to study economic and non-economic drivers that influence farmers' strategic cropping decisions. Howitt [15] developed a method to calibrate nonlinear CES production functions in agricultural production models using a minimum data set that usually restricts the modeler to a linear program. This approach has some characteristics of econometric and programming models which makes it more flexible to production specification than linear or quadratic programming models. The resulting models are shown to satisfy the standard microeconomic conditions. KAMEYAMA [16] introduced the primary model framework for regional agricultural production model, focusing on land use by crops and assessing the impact of climate change. They used Positive Mathematical Programming (PMP) for calibrating the land allocation in Adana province. They considered the impact of climate change only as the yield change (reduction) of crops.

The use of precision agriculture techniques is becoming increasingly common in the US. For example, some of the growers (of farm products, including of sugar-beets and dry beans), depend on global positioning system (GPS) or infrared images captured by aerial photography to see from space what they cannot see from the ground. This provides the farmers access to useful information that helps them in making informed decisions about growing farm products. In addition, the availability of such technologies is helping farmers in conducting tasks such as precision steering of tractors to space rows evenly.

There are also sensor technologies already being used in day-to-day farm operations, from which data can be collected. For such technologies to be useful, it requires that interfaces for adding such sensors are developed and made available.

GPS, satellite imagery, sensor technologies combined with meteorological information provide enhanced capability for improving farm practices and productivity. At the same time this poses the challenges of effectively analyzing the data and converting it to information that can be used by potential users.

The combination of ground-based and satellite-based remote sensing information, as well as weather data, could be used to more effectively recognize and predict plant health changes during the growing season, and to evaluate mitigation strategies based on data of past years. The economics of growing sugar-beets will include farm production, transportation, and factory processing of the beets.

Considering the US strength in technology and agriculture, a comprehensive economic model is needed to validate forecast models for increasing US competitiveness. Export of farm equipment worldwide is a major economic factor in US, particularly in North Dakota.

II. OVERVIEW OF PROCESS

1.1 Operation

Growers are responsible for choosing the seed that they plant: tilling, planting, growing, harvesting, and delivering the crop to the receiving stations. ACSC has 105 receiving stations for growers to deliver the load to and five processing factories. Beets get unloaded at a receiving station in piles and the responsibility shifts from grower to the ACSC. At pilers, the sugar-beet is cleaned and is piled 30' tall x 240' long for long term storage through the winter. The beets need to stay cold and frozen for long term storage or otherwise they will rot.

Once the truck is full to capacity, a new truck will take over loading the beets. The loaded trucks will then drive to the nearest sugar-beet processing plant or receiving station. At the piler, beets are cleaned of dirt and debris. Figure 2 depicts the storage and processing operation.

The sugar-beets are placed into a beater to remove mud and dirt and are then dumped into water-filled flumes which use buoyancy to separate rocks and gravel. Clean beets are then sent to the slicers and the beets are sliced to make cossettes that resemble cottage fries and shoestring potatoes. The cossettes are transported using conveyer belt to a diffuser or extractor. Cossettes are soaked in hot water to dissolve and remove the sugar from the sliced beets. Using osmosis, sugar is extracted from the cossettes that are immersed in hot water. The sugar water is saved and impurities are removed from this solution using milk of lime treated with carbon dioxide gas. Various stages of sugar-beet production are shown in Figure 2. The lime cake "mud" is separated from the juice. The beet pulp is squeezed, dried and formed into pellets to be sold for livestock feed and pet food.

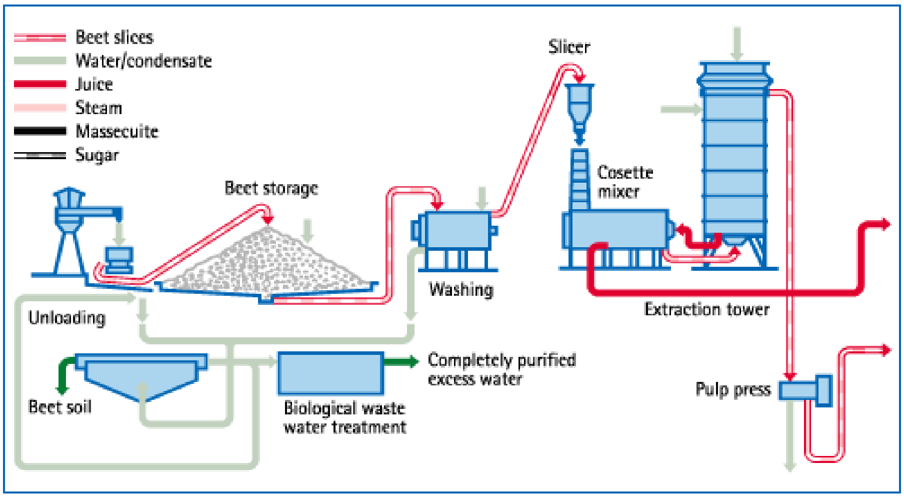

Figure 2: Storage and Processing Operation for Sugar-beet

Source: http://www.suedzucker.de/en/Zucker/Zuckergewinnung/

The sugar water is sent through a big round filter to clean it and remove other non-sugars. The juice goes into a series of big tanks called evaporators where some of the water is boiled off. After this process, the mixture contains more sugar than water. It is thick syrup which is again filtered to make sure it is very clean. This syrup is placed in large white pans to allow additional evaporation at low temperatures. What remains is thick heavy syrup which flows from one evaporator to another. During the crystallization process, the syrup is boiled, stirred, and cooled, and crystals begin to form. The solution is called massecite which is a syrupy liquid containing the grit of crystallization. The heavy liquid is centrifuged at 1,200 revolutions per minute and dried using filtered, heated air. The last of the liquid exits through minute holes in the centrifuge wall, leaving pristine white sugar crystals. The remaining bitter syrup is molasses, a product used in the manufacture of citric acid, antibiotics, yeast and other products. The sugar is then packaged in various types of packaging for sale in stores and restaurants and wholesale use. Various stages of sugar-beet processing are depicted in Figure 3.

1.2 Sampling

Load/trucks delivering the beets are sampled at 32% rate. This basically depends on the size of the farm. Smaller farms get sampled 100% and larger farms at 25% rate (1 of every 4 trucks). A grower can have multiple contracts in a field and based on that the sampling rate is determined. For example, a 150-acre field could be sampled at 20% of loads delivered and a 20-acre field at 100%. Beet samples go to the Quality Control lab in East Grand Forks and the sucrose content is analyzed and results are placed in the delivery records. Lab results indicate: sugar and sugar less molasses.

1.3 Payments

Consider the sugar content of the sugar-beet sample is reported at 18% and 1% is loss to malaises in the process and 0.5% is other losses, then the actual sugar content will be 16.5%. Average sugar content is about 17.75% sugar with a range of 16.5% – 19.5%. On the average, 350 lbs of sugar is produced per ton of sugar-beet. Payment to the growers is based on recoverable sugar per ton. Payments are determined 15-30 days after delivery on November 15. Dollars-per-Ton payment is spread over the entire coop for all stockholders, after losses are calculated. There are two forecasts, first one is in November 31 and second in March 31 which payments are made to growers. One final payment for the crop is made on November 5 of the following year. So the last payment is adjusted based on average cost to the company.

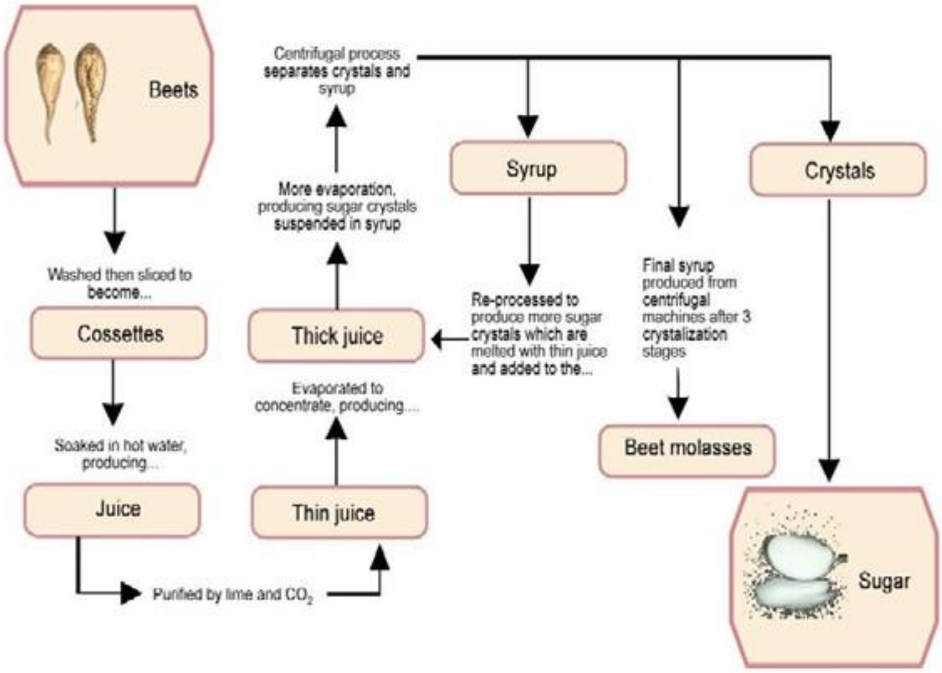

Figure 3: Stages of Sugar-beet Processing
Source: http://www.statcan.gc.ca/pub/96-325-x/2007000/article/10576-eng.htm

1.4 Prediction Models

Prediction models are more focused on tonnage of beets produced. Sugar content is highly affected by the weather condition at the time of harvest. In 2011, average sugar payment was $59/Ton of beets (32 or 33 cents per lb. of sugar) with a range of $49 - $69 per ton. Other places in US paid up to $72/Ton in the same year. Sugar-beet prices for the Red River Valley as compared to the rest of US are shown in Figure 4. Prediction of yield and verifying process capability was implemented in 2006 for the first time. In 2006, 8% of the harvest was left in the ground.

1.5 Harvest

When early harvest begins in early September or pre-pile (Sept.1 – Sept. 30), farmers mow the foliage off the beet plants which is called topping and cut off the tops of the beets using a machine called rotor beater. The mowed vegetation and beet tops are left in the field. A sugar-beet lifter uses a rotating disk to grab and remove the beets from the ground and place them into the vehicle. The beets are then dropped into a rotating basket which lifts the beet and places them onto a conveyer belt which will load the beet into a truck driving besides the tractor.

Sugar-beets have lower sugar content (about 13%) at that time. Beets are processed in 7-10 days. After Oct. 1 full harvest begins and beets are mostly stored in piles for long term storage and later processing. ACSC tracks completed/harvested fields, and growers are asked to identify their last load delivered to the receiving stations. By Oct. 2 we may have 10,000 acres of completed/harvested field.

After 50% of completed harvest, yield is determined and capacity is analyzed and the determination is made to leave certain percent of beets in the ground or not. Growers early on are asked to leave x% in the ground for late harvest. Every grower will have to leave the same percentage of their acreage in the ground. However, this has not happened since 2006. Early on going into harvest, if ACSC thinks that this may happen then the growers are asked to leave 5%-10% in their field. Growers may want to harvest the best beets first so they get premium prices for their beets as oppose to risk leaving it in the ground. Raw tonnage is increasing by 0.5 per acre per year but the sugar content is steady. The larger the harvest, the more risk there is, since weather can deteriorate the stored beet faster.

The more non-sugar present in the beet, the slower it is processed, therefore the higher the cost. 38000 tons/day of beets is 100% capacity of ACSC. Hillsboro and Grand Forks plants have had some capacity increase in the last five years. In 1998, 350,000 tons was hauled back to the fields since they were rotting due to warm winter weather. ACSC has a contractor who will identify farmers who will take discarded beets in their lands.

ACSC will acquire right to the land and establishes a payment period for using the land to spread discarded beets. Dollars/Ton payment is spread over the entire coop for all stockholders, after losses are calculated.

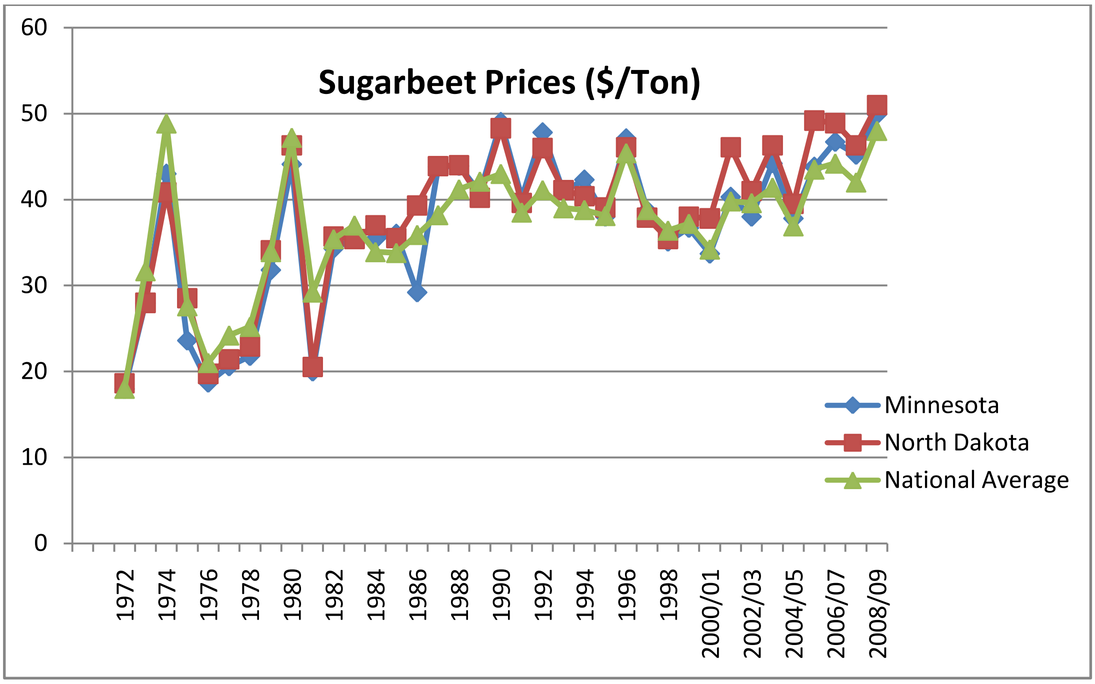

Figure 4: Sugar-beet Prices for the Red River Valley as compared to the National Average

1.6 Transportation

The transportation of sugar-beet crop from the farm to the plant and/or to piles is an important phase of the sugar-beet harvest and cost of production. The transportation also includes secondary tasks such as transportation of fertilizers, seeds, and pesticides with the use of tractor and combine.

ACSC has facilities located in five locations in Red River Valley. The sugar-beet producing farms are located in both Minnesota and North Dakota in the Red River Valley. The transportation of sugar-beets from the farms to the plants and storage pilers and then again from the pilers to the plant is a major cost to include travels from each field to said locations. Distances are calculated using GPS locations from each farm and GIS data for roads and highways.

III. ECONOMIC MODEL

Baseline data was collected to study the costs/benefits under the current system for farmers and processing plants. The proposed data system will help farmers to optimize use of fertilizers, pesticide, and other chemicals thus improving yield and reducing cost. Data can also help identify the sugar content of beets before harvesting. Optimizing the use of fertilizers, pesticides, and other chemicals reduces their negative impact on the environment. More effective identification of sugar content of beets will provide the farmer a time frame to harvest and haul the beets to the processing plants for the most payout. Farmers are paid more for delivered beets with higher sugar content. Data for the sugar-beet processing is collected according to the process flow chart shown in Figure 5. Total cost calculated considering production (sugar-beet growing) cost, processing (ACSC) cost, and transportation cost using the following equation:

$$TC = \sum \mathrm{Prod} + \sum \mathrm{Proc} + \sum \mathrm{Tr} \qquad (1)$$

Where TC denotes total production cost, Prod is the production cost, Proc is the processing cost, and Tr is the transportation cost.

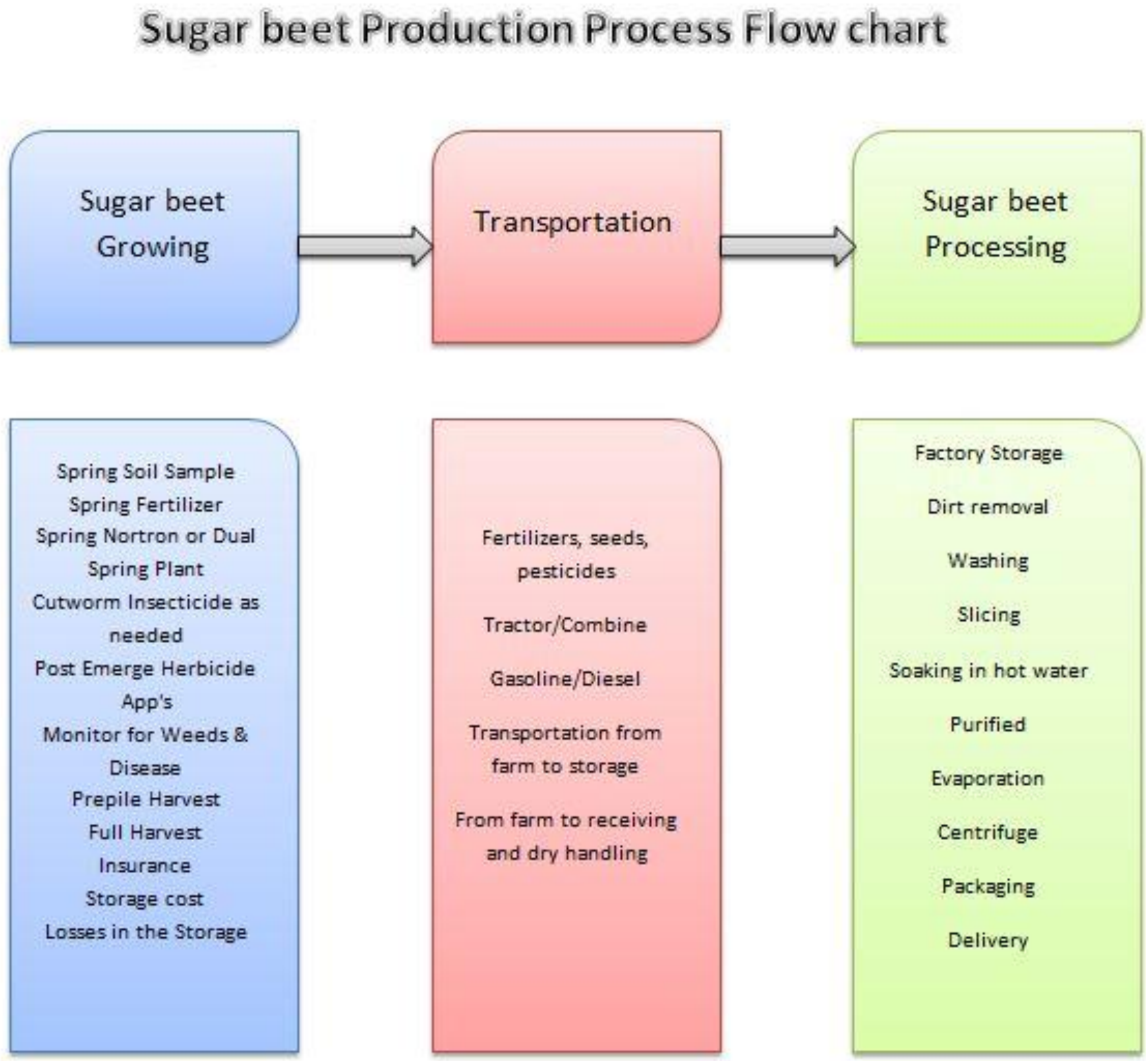

Figure 5: Sugar-beet Production Process Flow chart

IV. MODEL EVALUATION/EMPIRICAL RESULTS

Baseline data from the grower side is collected for the following attributes: Production Direct Expenses, Production Overhead Expenses, and Processing Direct Expenses. The cost associated with these attributes could be found in FINBIN Farm Financial Database at http://www.finbin.umn.edu/ as shown in the following tables:

Table 1: Sugar-beet Cost Analysis

	Sugar-beet averages					
	All Farms	2011	2010	2009	2008	2007
Number of fields	1183	210	251	223	227	272
Number of farms	631	116	134	120	123	138
Acres	166.16	178.18	160.08	161.16	156.37	174.77
Yield per acre (ton)	21.88	17.51	26.72	21.69	20.61	22.33
Operators share of yield %	100	100	100	100	100	100
Value per ton	46.14	60.1	54.23	39.15	41.09	37.94
Total product return per acre	1,009.65	1,052.70	1,448.84	849.25	846.98	847.28
Crop insurance per acre	44.21	118.69	0.93	42.78	75.35	-
Other crop income per acre	11.07	7.24	3.77	4.77	5.59	29.09
Gross return per acre	1,064.93	1,178.62	1,453.55	896.81	927.92	876.37

Table 2: Sugar-beet Direct Expenses

	Sugar-beet averages					
	All Farms	2011	2010	2009	2008	2007
Number of fields	1183	210	251	223	227	272
Number of farms	631	116	134	120	123	138
Seed	116.05	155.34	155.3	131.39	90.42	59.48
Fertilizer	77.42	97.41	75.56	98.89	72.8	50.48
Crop chemicals	83.98	84.62	70.63	60.24	94.82	104.61
Crop insurance	22.46	24.6	24.45	22.03	21.89	19.84
Fuel & oil	66.83	79.46	67	54.04	73.8	61.2
Repairs	83.75	97.69	93.27	80.78	77.07	71.95
Custom hire	14.72	14.38	18.43	13.87	16.5	11.17
Hired labor	27.06	23.83	27.95	28.81	29.7	25.53
Land rent	98.42	121.17	104.71	94.82	90.95	83.49
Stock/quota leas	117.42	138.56	130.44	104.15	92.57	118.34
Machinery leases	2.34	4.53	3.2	1.69	1.51	0.99
Hauling and trucking	8.85	9.59	8.1	9.85	8.3	8.56
Marketing	0.27	0.34	0.05	0.04	0.84	0.15
Organic certification	0.53	2.76	-	-	-	-
Operating interest	18.68	15.38	17.6	14.14	22.09	23.08
Miscellaneous	3.88	3.82	5.4	2.74	3.08	4.1
Total direct expenses per acre	742.63	873.47	802.11	717.47	696.35	642.96
Return over direct exp per acre	322.3	305.15	651.45	179.34	231.57	233.4

Table 3: Sugar-beet Overhead Expenses

	Sugar-beet averages					
	All Farms	2011	2010	2009	2008	2007
Custom hire	5.05	4.57	3.56	4.43	3.73	8.14
Hired labor	39.84	48.73	46.97	35.06	31.61	36.6
Machinery leases	11.84	10.1	12.42	11.07	13.78	11.84
Building leases	1.29	2.34	1.52	1.31	0.96	0.5
Farm insurance	9.89	10.98	10.86	9.87	8	9.65
Utilities	6.75	7.87	8.08	7.13	4.92	5.84
Dues & professional fees	5.71	5.85	5.33	5.81	4.65	6.63
Interest	16.3	15.54	14.2	14.63	17.11	19.35
Mach & bldg depreciation	70.18	86.75	84.48	65.86	62.02	54.41
Miscellaneous	8.98	11.97	9.54	6.77	8.32	8.34
Total overhead expenses per acre	175.84	204.7	196.95	161.93	155.09	161.3
Total dir & ovhd expenses per acre	918.48	1,078.17	999.05	879.4	851.44	804.26
Net return per acre	146.45	100.45	454.5	17.41	76.48	72.1
Government payments	13.4	11.31	15.14	13.08	14.12	13.29
Net return with govt pmts	159.85	111.76	469.64	30.49	90.6	85.39

Labor & management charge	97.65	116.87	105.84	95.06	94.01	80.28
Net return over lbr & mgt	62.2	-5.11	363.8	-64.57	-3.41	5.11
Cost of Production						
Total direct expense per ton	33.94	49.87	30.02	33.08	33.78	28.79
Total dir & ovhd exp per ton	41.97	61.56	37.39	40.54	41.31	36.02
Less govt & other income	38.83	53.72	36.65	37.75	36.7	34.12
With labor & management	43.3	60.39	40.61	42.13	41.26	37.72
Net value per unit	46.14	60.1	54.23	39.15	41.09	37.94
Machinery cost per acre	266.29	304.76	291.4	242.5	261.92	236.03
Est. labor hours per acre	5.53	5.72	5.6	5.35	5.45	5.51

The sugar-beet processing cost data are collected from ACSC and can be validated by the 2011 Annual report (ACSC, 2011). Table 4 calculates the payment per ton of beets and recovered sugar percentage from the given sugar percentage, tons of sugar-beet purchased, sugar hundredweight produced and member gross beet payment data. Figures 6-9 shows the trend for payment per tons of beet, member gross beet payment, tons of sugar produced, sugar and recovered sugar percentages respectively for the fiscal years 2007-2011.

Table 4: Sugar-beet Processing Cost

	2007	2008	2009	2010	2011
Sugar %	18.20%	18.10%	17.60%	16.70%	18.10%
Tons Purchased/harvested[1]	11911	11639	10349	9849	10902
Sugar Content of Sugar-beets	2168	2107	1821	1645	1973
Sugar Hundredweight Produced[2]	34814	34276	29611	27386	33494
Sugar produced Tons	1740.70	1713.80	1480.55	1369.30	1674.70
Recovered Sugar %	14.61%	14.72%	14.31%	13.90%	15.36%
Member Gross Beet Payment [1]	$ 599,106	$ 547,480	$ 533,842	$ 520,686	$ 796,090
Payment Per Ton of Beets	$ 50.30	$ 47.04	$ 51.58	$ 52.87	$ 73.02

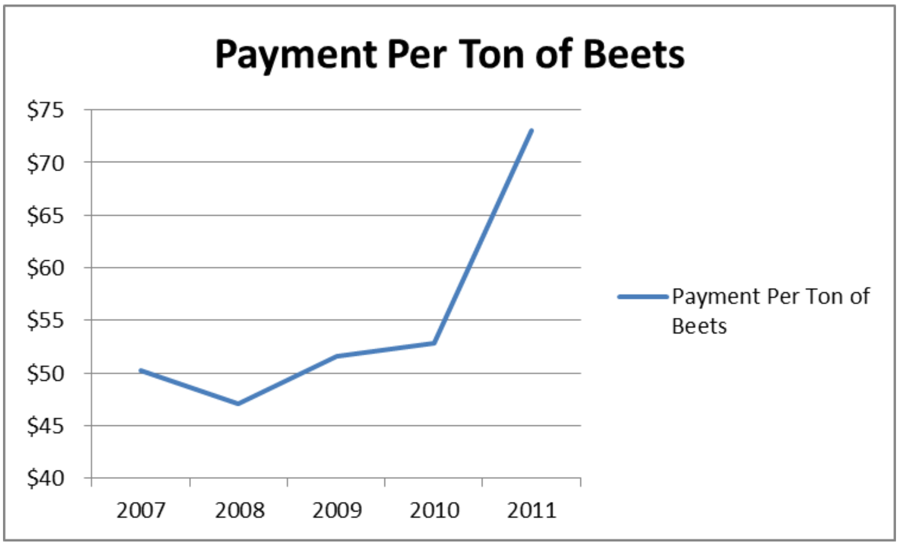

Figure 6: Payment Per Ton of Beets

[1]In Thousands
[2]The short hundredweight is defined as 100 lb

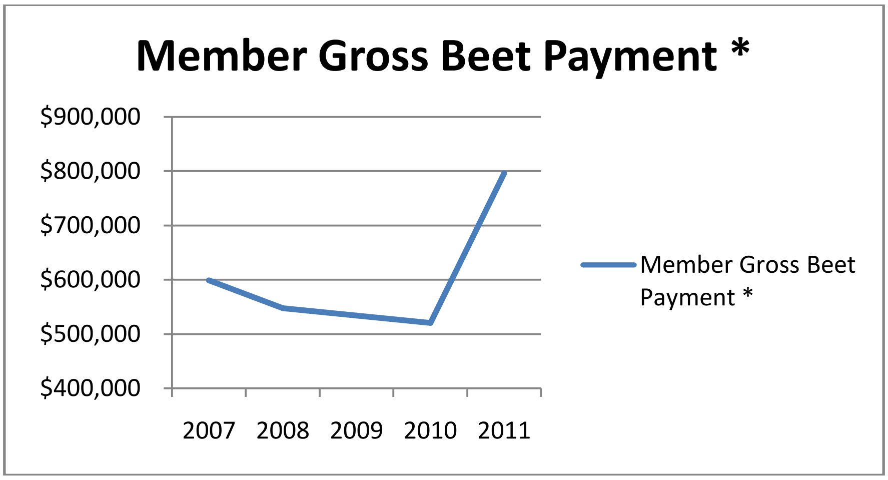

Figure 7: Member Gross Beet Payment

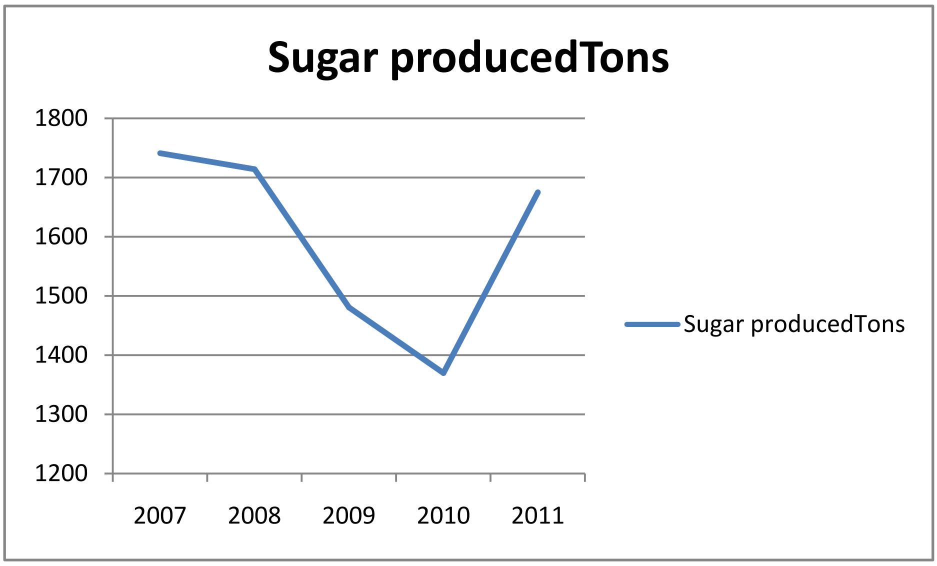

Figure 8: Tons of Sugar Produced

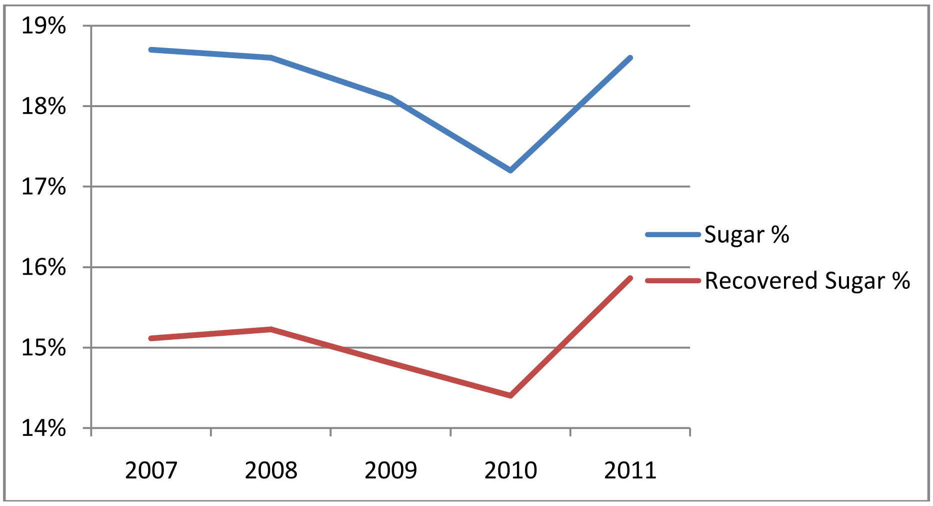

Figure 9: Sugar and Recovered Sugar Percentage

The cost associated with the transportation is also incorporated when performing the economic analysis. The Geographical Information System (GIS) is used to calculate the cumulative cost of transporting the annual yield from farms to the processing facilities. Locations of farms producing sugar-beet are acquired from ACSC data. They provided locations with latitude and longitude and yield information. Latitude and longitudes are then projected in GIS to produce the maps of all sugar-beet farms.

The Closest Facility analysis tool in ESRI® ArcGIS is used to generate the routes connecting origins with destinations. The summation of the distances of the routes provides the total distance travelled from the farms to the processing facilities. The cost of transportation is calculated with the help of this distance and total number of trucks used to transport the harvested sugar-beets.

Data analysis for the transportation of sugar-beet is shown in Figures 10-12. Facility ID 5 stands for Moorhead, 4 for Hillsboro, 3 for East Grand Forks, 2 for Drayton, and 1 for Crookston. To verify the results, total yield per year was compared with the yield per year in ACSC 2012 annual report. The results were close enough to confirm the analysis.

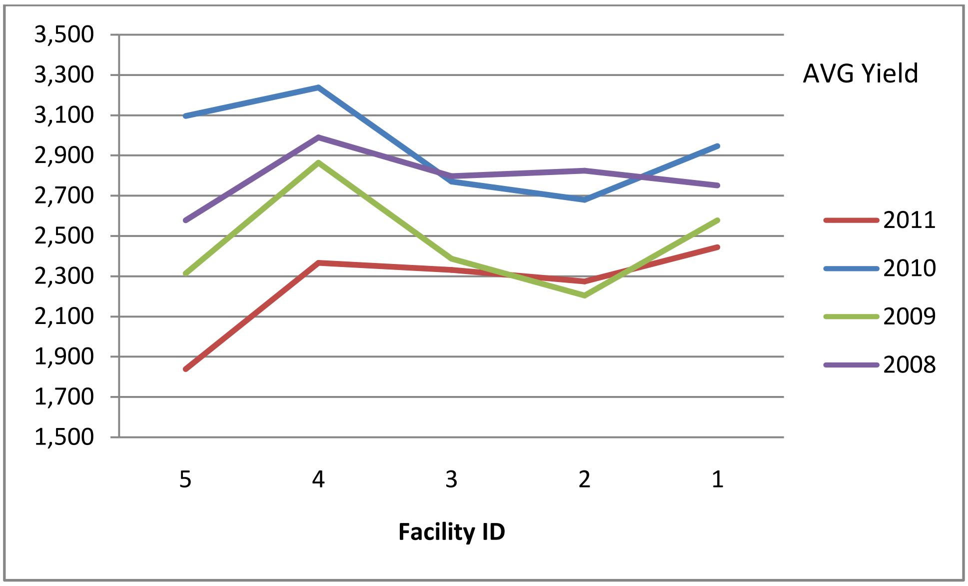

Figure 10: Sugar-beet Average Yield Transportation chart

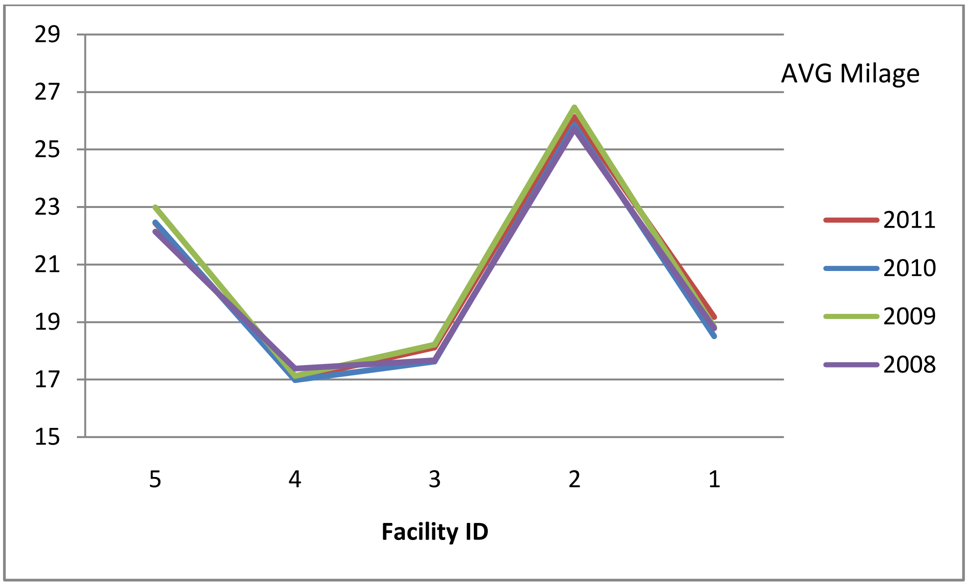

Figure 11: Sugar-beet Average Mileage Transportation chart

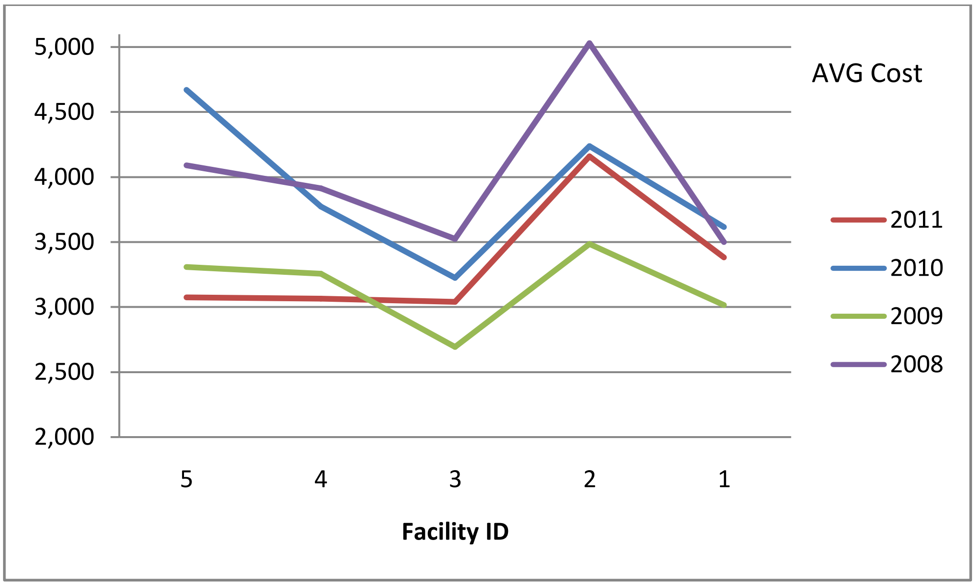

Figure 12: Sugar-beet Average Cost Transportation chart

Average yield per facility per farm reached a peak in most of the regions for year 2010 as shown in Figure 10, where 2011 resulted in the lowest average yield. Based on data shown in Figure 12, the lowest average cost of transportation per facility per farm for most regions was in 2009. The reason for this is not only the lower yield leading to the least average yield in region 2, but also the lower cost of fuel for 2009. Average diesel cost per gallon was above $3.00 for all years except in 2009 where the cost of fuel averaged around $2.68. Analyzing the figures show increased cost of transportation for facility 2 (Drayton) in 2008 which is due to the increase in yields for farms transportation (close) to Drayton (2).

V. CONCLUSION

We proposed a comprehensive economic model of sugar-beet production, processing and transportation in the Minnesota and North Dakota in the U.S. Data were gathered from FINBIN and American Crystal Sugar Company to analyze and define the important cost factorsfor profit and utility maximization. This can be done through developing a data-driven decision support system incorporating sensor data, satellite images, and weather information to allow farmers to improve the productivity of farm lands while reducing the needed resources for growing their crops. This data-driven platform will be versatile and can be applied to any crop. The proposed economic model will be helpful in building a data-driven platform in such a way to maximize the profit.

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