Strategic Fit Analysis: Using technology to reduce pre-harvest losses in sugar beets

by

Shelby K. Drye

B.S., San Diego State University, 2013

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2019

Approved by:

Major Professor
Dr. Keith Harris

ABSTRACT

The Imperial Valley sugar beet industry suffers a revenue loss of 1.1 million dollars on average each year. This loss is due to the amount of sugar beet acres replanted as well as abandoned. Current methods of crop management are proving the need for more advanced technology that will allow producers and processors of sugar beets to recover lost revenue. This thesis was undertaken to study the use of ArcGIS, a new technology created for on-farm management, as a tool to reduce crop loss in sugar beet fields.

The research not only found a revenue loss of 1.1 million dollars on average annually, but also the cause for the amount of sugar beet acres re-planted and abandoned, due, in part, to poor on-farm management of diseases. After interviewing growers, evaluating current farm technologies, and analyzing five-year production statistics, it is the recommendation of this study that ArcGIS would be best used to improve on-farm management decisions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

It is a genuine pleasure to express my deep sense of gratitude and thanks to both my mentor and teacher, Dr. Keith Harris, an associate professor of agricultural economics, whose work centers around supply chains within the context of a complex network of differing chain partners and relationships. His sense of devotion and interest in my related field of research along with his commitment is what helped me bring my project to completion.

I owe a deep sense of appreciation for the help given to me in this process by Dr. Terry Griffin, an assistant professor at KSU, as well as the help given to me by Rich Llewelyn, an extension assistant at KSU. My research could not have been accomplished without their attention to detail and extensive knowledge of agricultural practices.

It was a great honor and privilege to have the support of Dr. Allen Featherstone, Deborah Kohl, Mary Bowen and all other program coordinators that have made this journey possible, and a journey that I will always remember.

I would also like to thank Spreckels Sugar Co. for its support, both financially and with the time off needed to accomplish this degree.

Lastly, I would like to thank Lisa Drye and my beautiful wife, Irene Drye for supporting me during this whole process of completing my MAB course.

Due to the support of these many individuals, I now move forward in my life a more knowledgeable person in the world of agribusiness.

CHAPTER I: INTRODUCTION

1.1 Introduction to Thesis Topic

Spreckels Sugar Company (hereafter referred to as Spreckels Sugar or Spreckles) uses a method for data collection that is out of date. There are many new technological advances for on-farm data collection. Precision farming, smart farming, geographical information systems, are just a few terms that describe the ever-changing technological advances for better crop production. The implementation of these types of technologies will help to reduce crop loss, track crop diseases, improve plant populations, and create better on-farm communication in the sugar beet industry.

1.2 Industry Profile

The U.S. sugar beet industry covers 1.1 billion planted acres and yields an average of 29.5 tons per acre. There are twenty-two factories located throughout the U.S. (Appendix A & B) that are competing in the market place for the sale of granulated sugar. Each year companies that operate factories, plant, harvest, and abandon acres. Much of the abandoned acres are due to the various diseases and soil types found. The diseases that lead to crop loss vary in many of these locations. For example, Minnesota loses sugar beet acres to rhizoctonia and fusarium, other areas like Colorado, Nebraska and South Dakota loses acres to virus yellows as well as phytomass beticola. Companies in the sugar beet industry have tried several ways to track and manage sugar beet crop stressors that lead to crop loss, but every year sugar beet acres in these regions are abandoned leading to lost profits for both the producers and processors.

1.3 Company and Products

Spreckels is a subsidiary of Southern Minnesota Beet Sugar Cooperative, and is the producer of Spreckels Sugar products. The Spreckels Sugar brand of products are primarily marketed in the western half of the United States. Spreckels Sugar operates one beet sugar factory located in Brawley, California as well as a beet seed processing facility located in Sheridan, Wyoming. Spreckels has been supplying sugar products to consumers and customers for over 100 years. (Spreckels 2018)

Spreckels packages granulated sugar in 50-pound bags, 2,000 pound totes, and bulk truck and bulk rail deliveries. Spreckels products are marketed by National Sugar Marketing board to U.S. food and beverage manufacturers. (Spreckels 2018)

There are also co-products created in the sugar process, which include dried beet pulp and beet molasses. Beet pulp is the residue left after sugar is extracted from the sugar beet roots. The pulp is a major ingredient for milk production in dairies and is also used as part of the ration in feed for cattle. Molasses contains the portion of sugar that could not be crystallized into white sugar. Molasses is used as a principal product in the manufacture of yeast for fermentation processes. It is also used as an animal feed ingredient. Spreckles co-products are marketed by Midwest Agri-Commodities LLC, a leading marketer of sugar co-products around the globe. Midwest Agri-Commodities, globally, markets over 1.6 million tons of beet pulp, beet molasses, desugared beet molasses and betaine produced at 14 plants in Minnesota, North Dakota, Montana, Michigan, and California, to the livestock, dairy, and poultry industries. (Spreckels 2018)

Spreckels and other sugar growers lack the ability to rapidly track 24,500 acres for the causes of crop failure. Sugar beet crop loss leads to an industry-wide 1.1million dollar revenue loss each year. Inabilities to accurately track crop measurements and plant stand counts can cause incorrect forecasting for annual sugar production. Failure to follow proper crop rotations can prove devastating when it comes to disease and salinity in the soil. Incorrect farming practices for sugar beet planting can lead to a loss for the grower in the amount of $2,033 per acres and an additional $808 to replant the field on average, annually.

1.4 Company Mission and Vision Statement

1.3.1 Mission statement

Bring appreciable value to its shareholders, employees, and customers through environmental excellence, uncompromising safety and unparalleled integrity, quality, efficiency, and industry-leading innovation.

1.3.2 Vision statement

The vision is to be the preeminent integrated sugar producer in the world.

1.3.3 Statement of Purpose

The purpose is to unite producers in a cooperative venture that will enhance profitability and increase opportunities for its shareholders, employees and surrounding communities.

1.5 Problem Statement

The problems are the loss of acreage and lower than expected quality for the sugar beet crop, which has a negative impact on the relationship between the sugar producer and sugar processor. In order for Spreckels and sugar growers to produce the optimal sugar content from the crop and reduce crop loss, growers must rely on accurate and precise field data to address crop/field related issues in advance of the harvested crop.

1.6 Research Question

Does ArcGIS technology align with Speckle's sugar production and marketing requirements in the Imperial Valley sugar beet industry?

1.7 Research Objectives

This research seeks to find a way in which Spreckels Sugar can reduce the loss of beets and increase company profits. It also seeks to create a way in which agriculturalist and growers can analyze crop issues that later lead to sugar beet crop loss. The collection and management of data, along with the examination and determination of the results help to direct the outcome of the study.

1) Collect Data

Collect data related to growing, harvesting and processing of sugar beets (planted acres, measured acres, planting and sowing dates, seed spacing and seed size, variety type, replanted acres, herbicides, pesticides, nematode and rhizomania locations.)

2) Manage Data

Manage sugar beet field data by mapping field locations and creating a central data collection system.

3) Examine Data

Examine sugar beet data in order to improve the crop and to curb crop loss.

4) Determine Size of Crop and Losses

Determine the size of the sugar beet crop, crop health, potential losses and the cost of crop loss.

5) Examine Software

Research best fit technology that will help reduce sugar beet crop loss.

1.8 The Importance of This Research

Producers and processors of sugar beets in the Imperial Valley face challenges that make growing and processing sugar beets difficult. The causes of these difficulties cost the growers and processors - time, energy, money, and lead to inefficiencies in the six-month growing period and four-month harvest.

This research is intended to investigate methods of on-farm management as it relates to 24,500 acres of sugar beet production in the Imperial Valley. In order for the growers to produce the optimal sugar content from the crop, growers must rely on accurate and precise field data to address crop/field related issues in advance of the harvested crop.

1.9 Thesis Structure

The thesis is structured as follows: Chapter 1 contains the introduction to Spreckels Sugar Company and the sugar beet industry as a whole, along with the challenges it faces in growing sugar beets. Chapter 2 contains the literature review, which focuses on the many companies that face similar problems in the industry and some of the solutions used to address the challenge. In Chapter 3, the conceptual model is presented. Chapter 4 contains the research method and related data for the study. In Chapter 5, the analysis of data collected and tools for analysis are presented. Chapter 6, is the conclusion and summary of the research.

1.10 Global and Domestic Sugar Beet Production

Sugar beet (*Beta Vulgaris*) production in the United States began in the 1800s with the attempt to extract sucrose from the sugar beetroot for human consumption (A.W. Cattanach 2018). Many earlier attempts at sugar beet production were not successful. The sugar beet is a root crop that can grow in temperate climates. The growing season for sugar beets lasts five to six months. Crop maturation depends on factors such as the planting date, crop health, and weather patterns.

Beta vulgaris contains roughly 21% sucrose (A.W. Cattanach 2018) that is used as a high-energy human food additive, better known as sugar. Pulp and molasses are by-products of the sugar beet. The pulp gets sold as animal feed, and molasses is used for production in pharmaceuticals, baker's yeast industries, as well as natural health products and more (A.W. Cattanach 2018).

In global production, the United States ranks third after Russia and France, and produces an estimated 31,954,713 tons (Table 1.1) of sugar beets throughout California, Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Oregon and Wyoming (Table 1.2).

Sugar beets grow well in sandy and clay soils, and do not do well in cloddy and rocky soils. Even though the sugar beet has adapted to a wide range of climates, sugar beets are still primarily a temperate zone crop. Sugar beets can be produced in both hot and humid locations, but productions in these locations are more susceptible to diseases and other pests. Temperatures can affect crop yield and quality. The ideal temperatures for growing sugar beets are from 65 to 80 degrees Fahrenheit. Sugar beets generally adapt to most soils. However the presence of salts, clods, rocks and soil-borne diseases can affect the sugar beet growth, yield, and quality, which can lead to unwanted results for harvest and even crop failure.

Table 1.1: Production of Sugar Beets -Global Ranking- 2016

Rank	**Countries**	**Tons** (1,000 Tons)
1	Russia	45,057
2	France	33,688
3	United States	31,955
4	Germany	27,891
5	Ukraine	18,439
6	Turkey	15,000
7	Poland	12,350
8	China, mainland	11,469
9	Egypt	9,126
10	United Kingdom	7,291

Source: FAO

Table 1.2: Production of Sugar Beets by State -United States- 2010

States	Area Harvested (1,000 Acres)	Yield (Tons)	Production (1,000 Tons)
California	25	40	1,000
Colorado	27.8	29.5	820
Idaho	170	30.3	5,151
Michigan	147	26.5	3,896
Minnesota	442	27	11,934
Montana	42.6	29.5	1,257
Nebraska	47.5	22.6	1,074
North Dakota	211	26.5	5,592
Oregon	10.3	35.1	362
Wyoming	30.3	28	848
U.S. Total	**1,153.50**	**29.5**	**31934**

Source: USDA-NASS

The location of interest for this study is the southern tip of California just north of the Mexico border in the Imperial Valley (Figure 1.1). In this location, Speckle's owns its processing plant and contracts 24,500 acres of sugar beets with local producers. During planting and harvesting, high temperatures can range from 90 to 100 degrees Fahrenheit. The harvest season starts early April and can go into early August. In the Imperial Valley, many obstacles make growing sugar beets difficult. Most U.S. production records for tons per acre are set in this area because it has the lengthiest growing period until harvest; this is due to the many days of sunshine that the Imperial Valley receives annually. The Imperial Valley farming area consists of over sixty growers, all producing a range of acreage from 500 to 2,000 acres of sugar beets for a total of 24,500 acres. Due to the area's proximity to the Mexico border, growers have access to labor and can hire farm labor readily which is crucial during harvest. The Imperial Valley growing district for sugar beets is roughly 50 by 50 miles wide and receives its irrigation water from the Colorado River System via canal systems.

Figure 1.1: Imperial Valley, California, Sugar Beet-Growing Location

Source: Google Maps

1.11 Imperial Valley Cost per Acre for Sugar Beet Production

The cost of sugar beet production is estimated to be $2,278 per acre (Appendix A). It is essential to understand cost as it pertains to crop yield and quality. Growers in the Imperial Valley get paid by net tons delivered (yield), quality (purity), and sugar content (sugar percent). Net tons (Table 1.3) are the amount in tons of sugar beets delivered over the scale at harvest time; each truck delivered is weighed in before dumping. Quality refers to the amount in percent sugar (Table 1.3) that can be extracted from the sugar beet in percent, and the purity percent (Table 1.3) describes the percent difficulty it is for the extraction of the sugar out of the sugar beet.

In Table 1.3, the grower would get paid $4.22 per net ton delivered to the factory with 15 percent sugar and 57.50 percent purity. At the current sugar price of 15.91 per hundred weight of sugar (Table 1.4), profit margins are five percent lower for both the producers and processor. If a grower experiences crop failure or poor quality, the grower's profit could quickly disappear. If the factory cannot process sugar beets because of crop failure, it loses millions of dollars of potential profit. Both producers and processors are looking for new and innovative ways to improve quality and curb crop loss.

Table 1.3: Spreckels Sugar Beet Payment Formula – Growers –Example

Current NSP (Net Selling Price)	$0.20
% Purity of Beets Harvested	57.50
% Sugar in Beets Harvested	15.00
$ Price per ton	$4.22
Net tons	24.27
Total YTD beet payment by contract	$102.49

Source: Spreckels Sugar

Table 1.4: World Refined Sugar Price, Quarterly, and by the Calendar and Fiscal Year

Year	1st Q.	2nd Q.	3rd Q.	4th Q.	Calendar	Fiscal
			Cents Per Pound			
2012	28.92	26.46	26.49	24.12	26.50	27.75
2013	23.10	22.26	21.89	21.43	22.17	22.84
2014	20.26	21.46	19.79	18.68	20.05	20.73
2015	17.31	16.39	15.91	18.15	16.94	17.07
2016	18.84	21.82	24.94	24.93	22.63	20.94
2017	24.11	19.89	17.24	17.23	19.62	21.54
2018	16.36	15.35	14.68			15.91

Source: USDA

Throughout the last five years, sugarbeet varieties have improved due to new technologies such as GMO varieties, along with improved growing and management practices and yields have increased. On average, growers budget roughly $2,000 per planted acre of sugar beets to cover sugar beet seed, ground preparation, digging and any other subjective costs in the production of sugar beets (Appendix A). Even though yields have increased and farming practices for sugar beets have improved, the costs of processing and production have increased. The average cost of planting and irrigating sugar beets, is $2,033 per acre (Appendix A). Since 2013, the growers received on average a per-acre payment of $2,100 (Table 1.5).

Table 1.5: Annual Acreage, Yield, and Value of Sugar Beet in the Imperial Valley

Year	Acres	Yield/ Acre	Value/ Acre
2017	25,167	42.4	$2,150
2016	24,682	40.8	$2,000
2015	24,178	41.6	$2,050
2014	24,411	38.6	$2,100
2013	24,810	40.7	$2,200
Average	24,650	40.8	$2,100

Source: Spreckels Sugar

On average planting cost of $2,033 per acre (Appendix A) and a payment to the growers on average of $2,100 per acre, (Table 1.5) the growers profit on average is just $67 per acre. If a grower has crop failure, the operation could quickly lose profit per acre that is not harvested and delivered to the processor. If the grower needs to get a crew to remove rot, the grower could face losing not only his profit, but he or she could lose the growing cost of $2,033 per acre.

On-farm management and cultural practices are critical to a successful sugar beet crop. Manual methods were often used for on-farm management and growers did not have the power of technology to leverage on-farm decision making for better sugar beet crop results.

1.12 Cultural Practices for Sugar Beets in the Imperial Valley

The first part of planting a sugar beet field is choosing the appropriate field for the crop. In the Imperial Valley, ground is limited and growers have to choose which crop to follow the sugar beet portion of the rotation. The best crop to follow is Sudan grass (*Sorghum*). Other crops such as produce crops including onions (*Allium Cepa*), lettuce (*Lactuca Sativa*), and peppers (*Capsicum*) may leave residual nitrates that lead to poor sugar beet yields. Crop rotation is one of the most significant contributors to a healthy sugar beet crop. There are many different soil types in the valley: fertile, sandy soil, clay soil, and even saline soil. These different soils can affect sugar beet production in different ways. A grower can alter sugar beet varieties to help fight some of the various soil challenges faced.

Next, the grower selects seed varieties. There are many varieties for growers to choose from and there are two significant seed distributors in the Imperial Valley area, Holly Seed Company and Beta Seed Company. Varieties are essential in the fight against a range of challenges presented by different soils and disease that the grower will face during the growing season. The grower is tasked with choosing the right seed variety for the challenges faced during the growing season. Some varieties perform better than others on different soils, and some varieties have better resistance to diseases than others. There are both early and late maturing varieties; the grower must decide which fields will be harvested in the early harvest (April – May) and which will be harvested in the late harvest (June-July and into August).

Row width, depth of seed, and plant population all play a significant role in yield and quality results. A thirty-inch seedbed, without clods, and proper seed spacing, 3-4 inch is recommended to maximize yield. Some growers may plant at relatively high seeding rates and then thin the plant stand to the desired spacing. The sugar beet seed produces higher yields in non-cloddy seedbeds; growers will use a soil mulcher on the seedbed to eliminate clods before planting. Seed to soil contact is vital for vigorous and healthy germination. Sugar beet seed is planted with precision row crop planters. Planting is contracted between September and the end of November.

When planting is completed, the correct watering method must be used. Furrow irrigation can be riskier than sprinkler irrigation. Sprinkler irrigation results in better soil to seed contact and pushes salts down, leading to better plant populations. With sprinklers, salts tend to leach into the soil profile as water percolates downwards into the soil. However, sprinkler use is more expensive. Furrow irrigation can leach salts into the seed row and can also lead to dampening off, the drying out of the seedbed, quickly killing off the seed germ. There is almost a 90% germination rate under sprinklers, and it is 20% less under furrow irrigation.

After the crop emerges, cultivation must be used along with pest and disease management, which if done incorrectly, could lead to crop failure. The grower must also establish a schedule for spraying. All varieties of sugar beet seeds for the Imperial Valley are GMO, and this makes weed control easier for the grower. GMO varieties can be sprayed with Roundup™,which will not kill the sugar beet plant. Weed control is essential to the sugar beet plant at an early age. Crop failure can occur when the sugar beet is in its cotyledon stage and has to compete with unwanted grasses or weeds. Unwanted grass and weeds can use up the fertilizer that is vital to the sugar beets health early-on.

Cultural practices for sugar beet planting are critical to sugar beet survival, yield, and quality. Strict management practices must be followed and adequately documented. The ability to do this with new technology will produce a higher-yielding crop and lessen the chance of crop failure in the Imperial Valley.

1.13 Influence of Cultural Practices on Sugar Beet Quality

At Spreckels, the Agricultural Department works closely with over 60 growers to grow, manage, and harvest over 24,500 acres of sugar beets. The agricultural staff and its research staff, along with growers, are always concerned with how current cultural practices affect sugar beet quality. The agriculture staff and growers are looking for improved ways to manage sugar beet field data and operations to make and recommend better culture practices for sugar beet production. Both growers and the agricultural staff are proud of the crop when yield and quality are better than the previous years, but are disappointed when yield and quality decrease, a good year would be a range from 55 tons to 60 tons an acre while a bad year would range from 40 to 50 tons an acre.

After understanding the cultural practices for sugar beet growing, the agricultural staff examines how these practices affect yield and how yield affects sucrose percentage in the sugar beet. Poor management practices over many years have affected sugar beet quality and led to sugar beet crop failure. The agricultural staff at Spreckels Sugar and growers believes that field management practices can change. They believe that there is a way that farming practices for sugar beet production can be managed to produce a higher yield and quality.

Even though acts of God can never be changed by the producer, predictions can be made and many growing practices can be adjusted. Irrigations, plant populations, seed varieties, tillage, nitrogen, and pest and diseases control patterns as well can be correlated and studied from year to year. Data control and field mapping for these practices have been in place, but the manual method of data collection is no longer a viable option, because it does not deliver data to the grower quickly enough so that they can make fast enough on-farm decisions. The manual method of data collection cannot collect as much data as fast as the automatic method can to predict crop yield loss, decreased sugar quality and crop failure. Both the agricultural staff and growers agree that an improved method is needed for data collection, management, and analysis. Both growers and the agricultural staff believe this can be accomplished and will increase the profit margin for sugar beets and reduce crop loss.

1.14 Problems That Lead to Poor Quality and Crop Loss

Many factors lead to poor quality and crop loss in the Imperial Valley. Poor quality and crop loss can lead to millions of dollars lost for the producer and processor. Everything from weather patterns, pest populations, disease populations, and poor crop management practices can cost producers and processors and could even potentially lead to the destruction of the sugar beet industry in the Imperial Valley as it is known today. The sugar beet industry in the Imperial Valley is worth over $53.6 M. The sugar beet producer and processor employ over 1,500 people every year locally. The sugar beet industry supports local business by purchasing local products for factory operations. It is important to the industry to look at anything that could potentially affect this type of revenue and job security or even things that might improve or create more revenue and job security (Ortiz and Dessert 2018).

Several diseases in the Imperial Valley affect the sugar beet crop; two of the worst are rhizomania and nematodes (Figure 1.2).

Figure 1.2: Rhizomania (left) and Nematodes (right), Imperial Valley, California

Source: John J. Gallian Source: Shelby Drye

These two diseases can lead to plant rot (Figure 1.3), but can be avoided by crop rotation and knowing where disease populations are in the growing region. Several fields are planted each year and abandoned due to rot from these diseases. Until now, there was no credible technological advance to track disease population size and locations.

With today's technological advances, these diseases could be tracked on a map to pinpoint accuracy allowing the grower to avoid these fields or treat the areas within the field. The grower would even be able to hand-select varieties that have been genetically modified to fight these diseases and use them in the field with high populations of these diseases.

Figure 1.3: Rot in Beet (Left), Rot in Field (Right), Imperial Valley, California

Source: Shelby Drye Source: Shelby Drye

Another problem that sugar beet growers face in the Imperial Valley is soils high in salinity. The Imperial Valley is known for its extremely high-in-salinity farming areas. Salinity can kill the seed and germination before it even has a chance to emerge. High levels of salt in the soil dehydrate the sugar beet at its earliest stage and sometimes affect the seed's germination before it cracks. Salt destroys the inner water balance of the sugar beets cells. Unlike other diseases that affect the sugar beet crop toward the end of harvest in warmer temperatures, soils high in salinity will affects the crop early in the growing season. This means that the grower could lose out on profit before the crop matures and is harvested (Figure 1.4).

Figure 1.4: Poor Stand Due to a High Salt Content, Imperial Valley, California

Source: Dimitri Boratynski

Crop loss to saline conditions can be avoided if fields are tracked on a map along with their salt content. According to research, there are two ways this can be avoided. One is the use of sprinklers, and the other is avoiding the field altogether (Coons 1953). If the grower has a better way to know that the field he or she is leasing has a high salt content, then they could make the decisions to germinate that field with sprinkle's to push the salts down through the soil profile. He or she could also choose to rent another field and avoid that one altogether. Currently, in the Imperial Valley, there is no tracking of field salt content for sugar beet production.

Another major hindrance to sugar beet quality is nitrogen levels in the soil. A study was done in 1958 by a group of soil scientists studying how nitrogen affects sugar beet yields. The study was to determine if the increase of yield by the use of nitrogen would lead to a decrease in quality. The study found that on "Average beet yields in the United States have increased from 10.8 tons in 1937 to 17.2 tons in 1957. These phenomenal tonnage increases, however, are not accompanied by increases in sugar content" (Smith, Downie and Jesnsen 1958). High levels of nitrogen hurt sugar quality. This is a sugar beet growing management problem, due to the lack of data for nitrates on sugar beet fields in the Imperial Valley. Spreckels Sugar needs to collect data that shows regions of high nitrate levels or the use of fields for sugar beet production that have just come out of a produce crop. Produce crops require high levels of nitrates and a sugar beet crop should not follow directly after them in the rotation.

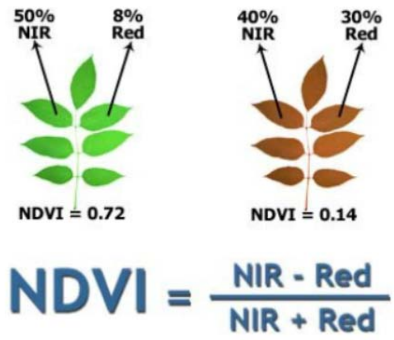
CHAPTER II: LITERATURE REVIEW

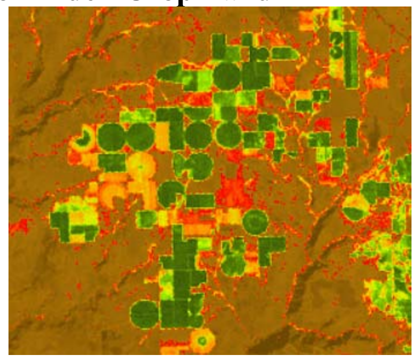
2.1 Methods to Curb Poor Quality and Crop Loss

Geographic information system (GIS) and remote sensing is used in the cranberry industry to detect yield loss and crop health. The research showed that "over the past few decades the definition "management units" has changed from a "whole farm" approach to a "prescribed" field-specific and even site-specific treatment" (Oudemans , et al. 2002). In this study, data was collected using both GIS and global navigation satellite systems (GNSS) methods during harvesting. Oudemans states that this technology is underutilized in most crops today and if used could potentially improve on-farm productivity. Furthermore, he explains the capacities of these technologies to track spatial variation in water stress, nutrient availability, disease and grower controlled inputs, such as fertilizers and fungicides. The study results suggest that these technologies can track variations in the crop's responses to on-farm cultural practices. The tracking of these variations in crop health is done from a georeferenced satellite image by way of normalized difference vegetation index (NDVI) (Figure 2.1) and SIPI (Structural independent pigment index) technologies to analyze various colors that represent crop stress.

Oudemans study concludes that more available, detailed and accurate yield data can be tied to individual fields, which give the grower the opportunity to develop a system that leads to a more uniform crop, in this case, a more uniform cranberry culture with less crop loss and more consistent yields.

Figure 2.1: Normalized Difference Vegetation Index-Crop Land





Source: www.ece.montana.edu   Source: ArcMap

This type of technology could benefit the sugar beet industry, both producers and processors of sugar beet crops during harvest and pre-harvest. The ability to see crop stressors over time and overlay them with previous years allows growers to associate these colors with different types of stressors that they could then avoid by making better beet crop management choices.

2.2 Adopting Precision Farming Methods

Six leading-edge adopters of precision farming found that precision farming if adopted can revolutionize farm management (Batte and Arnhold 2002). The results suggests that by studying six leading-edge adopters of precision farming and the benefits in the adoption of new and improved precision farming tools. Furthermore, the six adopters have been able to improve input use that lead to lower on-farm production costs while increasing output that leads to higher profits. The research reports that out of the six leading-edge adopters, the most valuable asset to them was not the variable rate application technologies, but rather the information-gathering technologies that are available through precision farming, such as yield monitors, and/or mapping with data collection. His research touches on the profitability of using precision farming tools for on-farm management and some of the risks in doing so. Batte believes that precision farming tools are an emerging technology; they are still in need of improvements. However, Batte believes that precision farming tools will pave the way for both farmers' and society's ability to improve production efficiency and environmental sustainability in farming. Data collection, by way of precision farming, could dramatically alter sugar beet production.

2.3 Comprehensive Approach to Farming

Grisso, "management is the key to successful farming". This study is centered on precision farming versus traditional agriculture practices (Grisso, et al. 2009)

> "In PF (Precision Farming), the farm field is broken into "management zones" based on soil pH, yield rates, pest infestation, and other factors that affect crop production. Management decisions are based on the requirements of each zone, and PF tools (e.g., GPS/GIS) are used to control zone inputs. In contrast, traditional farming methods have used a "whole field" approach where the field is treated as a homogeneous area. Decisions are based on field averages and inputs are applied uniformly across a field in traditional farming. The advantage of PF is that management zones with a higher potential for economic return receive more inputs if needed than less productive areas. Therefore, the maximum economic return can be achieved" (Grisso, et al. 2009)

Grisso's collected data from precision agriculture tools, such as yield monitors, yield maps, and soil analyses. He states that the goal is to collect data from year to year in order to compare and contrast by location and field, along with seed varieties and diseases in different locations. The study uses the analysis of data to draw a conclusion on how a corp should be managed. Grisso states, "Precision farming relies on three things: information, technology, and management".

2.4 Detecting Plant Stress Due to Heterodera Schachtii and Rhizoctonia Solani

There is an ability to use remote sensing in combination with GIS to effectively detect and map symptoms caused by beet cyst nematode, *Rhizoctonia solani* and root rot (Hillnhutter, et al. 2011). Research shows that these symptoms affect canopy health, thus making them a prime target for site-specific treatment and the use of precision agriculture tools. His research shows the early and late onset of *Heterodera schachtii* and *Rhizoctonia solani* and the detection of both in a sugar beet field. The study concludes that this method can be used to manage fields to reduce crop loss because of diseases. If a grower sees a field is infected, the grower can move that field's harvest period up in the schedule before it dies and has to be abandoned.

2.5 Detecting the Movement of Rhizoctonia Solani in Soybean Crops

Tracking the distribution and colonization of soybean by *Rhizoctonia solani* AG11 in fields rotated with rice. In the research, *Rhizoctonia Solani* is tracked and mapped throughout many years to show its movement within a field sector. The research for this article put to use GPS, ArcGIS 10 and ESRI to create shapefiles for locations in fields of soybeans that had a high population of *Rhizoctonia solani.* The method in which this was done was first to sample the field areas that had a history of *Rhizoctonia solani* and record a GPS location where the sample was taken. Then an assessment of the soil inoculum potential and plant colonization was done by the use of Trac-Mate™ software. Then a stand assessment was done from the soil collected at each GPS point. The data was then put together using Open Office for data analysis and later a spatial relationship was established. "This spatial study allows the opportunity to examine the impact of *Rhizoctonia solani* AG11 on the development of soybean in the field." (Spurlock, et al. 2016) Moreover, this research will allow a grower to spot treat fields for diseases like *Rhizoctonia solani*. It will also allow for seed treatments that can help fight these diseases and improve stand establishment.

2.6 Variations in Sugar Beet Yield and Quality Due to Different Soil Types

Variability of sugar beet cropping areas when it comes to variations in soil, the research looked at field scale correlations of sugar beet yield and quality with variation in a range of factors both separately and in combination. The research aimed at mapping the variability of potential driving variables of sugar beet yield values and found that “sugar beetroot yields are positively correlated with the spatial distribution of crop plant population, soil organic matter, and soil moisture, but negatively with weed density and canopy temperature” (Mahmood and Murdoch 2017).

2.7 Mobile and Satellite Technology in Agriculture

Welte researched the ever-changing size of the farm and farming landscape; how no two farms are alike, each has its management structure, equipment, farm plan, and way of doing business. Technology is a significant part of agriculture. Now that technology like cell phones and iPads are available, there needs to be a way to use this technology for field data collection and interpretation. Though mobile platforms do not yet have the ability to meet farm technology needs. Satellites are becoming more prevalent in picking up the slack where cell towers cannot. According to *Big Data Considerations for Rural Property Professionals,* growers and implementers of on-farm data collection systems or technology should consider the impact of poor wireless connectivity for emerging precision agriculture tool (Griffin, et al. 2016). It is understood that the use of this technology must be cost-effective for growers to adopt. It must also be easy and simple to use in the field, tractor, or work truck. “Welte states that there needs to be a large amount of infrastructure by way of cloud storage services for in-field data collection when done by tractor or walking in a field." His idea for "the simplest method of data collection is manual input; this traditionally consists of handwritten notes mad with pen and paper. Long standardized forms tend to overwhelm the operator if particular attention is not paid to the user experience" (Welte, et al. 2013). It is critical to have simple to use, specialized apps, or applications to get data from the field or farming operation into the cloud for better decision making. Greater data collection will lead to more efficient farming practices.

2.8 Importance of Committed Community to Agricultural Technology Platforms

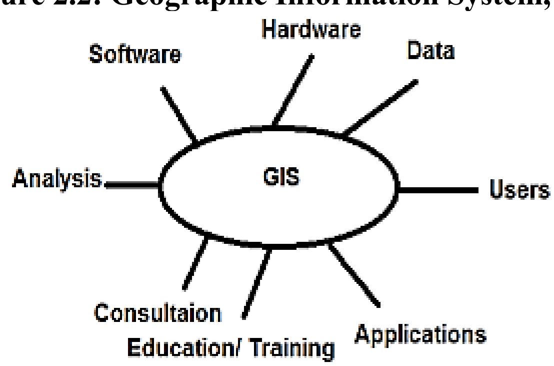
There are many designs for agricultural technologies and their platforms. When looking at what technology and platform can be used for a specific farming operation, many can be found. There are many technologies that get started for the agriculture industry, but "have long suffered from fragmentation in model implementation…many models are developed, there is much redundancy, models are often poorly coupled, model component re-use is rare, and it is frequently difficult to apply models to generate real solutions for the agricultural sector." (Janseen and Potor 2017)

Finding the right technology platform for data collection is important to Spreckels Sugar's success at a more successful crop and harvest season. It is essential to assess relevant technologies in the agriculture industry and the company's success in implementation and continued support for those products. As a company, Spreckels Sugar must make sure that the implementation of this new technology will be adopted by its growers, is easy to use, and is built on a platform that will work for them.

2.9 Geographic Information System.

GIS tools enable some users to organize geographic data so that a smart decision can be made for s specific project or task (Soomro and Rahim 2015). ESRI Inc. is known to be the main research and development organization to support tools for GIS. ESRI Inc. has developed several products that help to navigate GIS platforms, products for desktop, server and mobile applications. The primary tools for desktop use are Arc Map, Arc Catalog and Arc Toolbox. Figure 2.2 shows how these various tools relate to geographical information systems for agriculture and its environment. GIS can only work when these eight things are in place: software, hardware, data, applications, education, training, consultation, and analysis. Software is what is needed to make hardware useful. In this case Arc Map, Arc Catalog and Arc toolbox are all software and the phone that is used to view the software is the hardware. Users are accentual to this framework because it is the user that collects the data and must be trained on how to do so. Data is only as good as the individual collecting it. Good data is needed to make a good analysis for a better outcome.

Figure 2.2: Geographic Information System, Environment



Source: (Soomro and Rahim 2015)

Understanding ESRI's ArcGIS program is essential to understanding how all in-field data are collected and stored in one database that makes it easy to analyze and to make faster decisions in agriculture. If Spreckels Sugar and growers can harness this knowledge,then growers will be more successful at making decisions which will affect the outcome of the sugar beet crop.

CHAPTER III: CONCEPTUAL THEORY

3.1 Introduction

For many years the agricultural industry has used some form of technology to further explore crop performance. Spreckels Sugar was founded in 1905 and the company has not developed a method to track and manage 24,500 acres of sugar beets. Many factors can affect the health of a sugar beet crop. Some factors can be managed and others cannot. For this reason, the sugar beet industry has suffered losses, which have put some producers and processors out of business. For example, in 1870 there were eleven sugar beet factories throughout the state of California, now there is one, Spreckels Sugar. Every year Spreckels Sugar and its 60 growers face shrinking profit margins both at the factory level, as well as the farm level. Spreckels Sugar and its growers can no longer operate the way they have in the past.

3.2 The Role of Spreckels Sugar's Agriculture Department

Spreckels Sugar's operation is made up of many different departments. The Agricultural Department manages the contracting of 24,500 acres of sugar beets. The department is made up of one Agricultural Manager, three Agriculturists (field men) and one Agricultural Administrator. It is responsible for overseeing the operation from the field to the factory during harvest, including negotiating contracts for beet acres with growers for each new planting season. The Agricultural Department manages all data collected on sugar beet fields each year. Recommendations are made to growers for best-growing practices according to data analyzed. This research will emphasize job and responsibilities of the three Agriculturists. It will review how field data is collected and managed to help growers produce the best sugar beet crop possible and minimize sugar beet crop failure.

The Imperial Valley, refer to (Figure 1.1), is split into three districts (North, Central, and South) with one agriculturist per district.

3.3 Delivering on the value proposition

Delivering on the value proposition is met when the planted acres of sugar beets supplied by the growers match's acres of sugar beets demanded by Spreckels Sugar. Hence, increases the chances of meeting the firm's profit objective. Success will be defined by the reduction in the average amount of acres replanted and abandoned that are affected by controllable crop stressors. Success is met when zero percent crop loss by controllable crop stressors is met and when the quality of the crop meets or exceeds forecasted production totals annually.

3.3.1 Matching Supply with Demand

Spreckels Sugar seeks to match supply with demand of sugar. On average each year, Spreckels Sugar contracts each year, with the local growers, for the production of 740,790 tons of sugar beets. The sugar processing facility operates April through July. In order to meet profit maximization, Spreckels Sugar and growers must work together to produce and process at or above the amount of 740,000 tons for the harvested year.

3.3.2 Profit Maximization through Quality

The quality of sugar beets is a substantial part of Spreckels Sugar's value proposition. The producer's and processor's profit is gained by the quality of the sugar beet crop. Profit is lost when the quality (tons, sugar, and purity percent) of the crop is lower-than-expected. The abandonment of acres or production of lower than forecasted quality can be critical to the financial success of Spreckels Sugar. The sale of sugar is subject to the market price that does not fluctuate very often. Spreckels Sugar profits by way of increased acres and good quality and high yielding sugar beets. Spreckels Sugar seeks to maximize the crops yield of extractable sugar per acre and the grower seeks to maximize tons per acre as well as extractable sugar content per acre.

CHAPTER IV: METHODS

4.1 Current Methods for Field Data Collection

At the start of a new planting season, each Agriculturalist prepares a Microsoft Excel file. The file has several headers for data that is categorized and collected during planting, growing, and harvesting. There are many issues with this method of data collection. For instance, data is spread out between multiple departments and not easily tracked down to combine and analyze. From year-to-year, the files often are misplaced by being stored improperly on company server files. The data files are not linked to field locations on a map, so the big picture is often skewed.

4.2 Role of Agriculturist during the Planting Period.

During planting, it is the job of the agriculturist to collect start dates for planting, water dates, seed spacing, seed size, variety type, herbicides, and pesticides.

4.3 Role of Agriculturist during the Growing Period.

During the growing period, the agricultural staff collects data on planted acres, measured acres; replant acres, mileage from the field to factory, salinity locations, nematodes, and rhizomania locations.

4.4 Role of Agriculturist during the Harvest Period.

Agriculturists collect data related to harvesting activities and quality of the sugar beets along with working with growers to identify and move fields up in the harvest before they are destroyed by rot. They also manage load deliveries from field to factory according to inventory needs.

4.5 Importance of Field Data Collection System.

During planting, growing and harvesting, it is the job of the agricultural staff at Spreckels Sugar to track, collect and manage data on the sugar beet crop. The following are several things that if tracked and analyzed each year quickly, can make a big difference in the outcome of the crop and the amount of rot that will present itself at the end of the harvesting season.

4.5.1 Tracking Management Practices

Tracking cultural practices for sugar beets is vital because each grower will plant, irrigate and cultivate using different methods. When planting, one grower may have a deeper seed depth or spacing than another, and this would depend on the type of ground he or she is growing on. Some growers may germinate the seed using sprinklers and others may use furrow irrigation. Some growers choose not to cultivate. Cultivating is not necessary, because sugar beets are GMO and can be sprayed. Even though this is the case, some growers might still cultivate in order to open up the furrows for better permeability of applied nitrates. Cultural practices will play a significant role in determining what leads to sugar beet crop loss during planting and harvesting of sugar beets. It is critical to track the cultural practices for each grower on an annual basis, so that it can later be analyzed to determine what cultural practices might have affected crop loss.

4.5.2 Tracking Nitrogen Use

A grower’s nitrogen program can impact the quality of the crop. It is the job of the agriculturist to inform the grower of high nitrate levels in the soil. Tools for monitoring residual and added nitrates are needed to collect and analyze samples. The harder the sugar beet has to search for the nitrogen, the more sugar it will store. If nitrogen is readily available to the sugar beet plant, it will not struggle and will yield less sugar. If this is tracked well, the growers will have a better chance at a higher yielding crop.

4.5.3 Tracking Crop Size

Tracking crop size is essential for the Agricultural Department and company. The size of the crop can vary from year-to-year, and the company's financial forecast is based off the crop size. At the beginning of each year, acreage measurements are taken on each field. The measurements are taken using an aftermarket GPS application, generally installed on an agriculturist's smartphone. Having each acreage measurement on each field compiled in a database will help the company determine from year-to-year how the crop is growing in size.

4.5.4 Tracking Crop Health and Root Samples

A ten-foot row of sugar beets is taken out of 36 fields once a month in the four months leading up to harvest. The sugar beet samples are then tested in a lab for quality and size. An average of all 36 fields is taken and used to determine the start date for the sugar beet harvest.

It is also important to track the overall health of the crop and the effect the environment has on it. The amount of annual rainfall and annual sunshine are essential to the crop's photosynthesis and the storing of sugar in the sugar beet.

4.5.5 Tracking Crop Diseases

Different types of diseases can affect sugar beets and lead to crop failure. The two that most affect the Imperial Valley growing regions are rhizomania and nematodes. It is crucial to track these diseases as they move around the growing area. If these diseases are not tracked accurately and are allowed to build up in the soil, they can have catastrophic long term effects on the sugar beet industry in the Imperial Valley. On the other hand, if they are tracked accurately and with good visual representation, they can be controlled with various crop rotations as well as field rotations. Tracking these diseases is vital because they can spread by the use of farm implements from one field to another. Digging equipment for sugar beets is often shared between growers for harvest. Technology is needed to be more accurate when it comes to tracking diseases. A more technical tool, other than Excel, needs to be explored.

4.5.6 Tracking Crop Salinity

Areas of high salinity in the Imperial Valley can render ground useless for growing sugar beets. On the other hand, there might be some sugar beet fields where high salinity only affects a small portion of a large field. The sugar beet grower might still decide to lease the field for use in sugar beets, but will call Spreckels Sugar's agricultural department to ask about the field's disease or high salinity history. Since disease and high salinity have such a significant effect on sugar beet crop loss and yield loss, it is vital for Spreckels Sugar to keep a good history of previously infected fields and their locations. If the histories of sugar beet fields that are affected with high salinity are kept, growers will not continue to grow on the same bad ground, getting the same bad results.

4.6 Effects of an Outdated Data Collection Method for Tracking Sugar Beet Production

4.6.1 Crop Losses Each Year

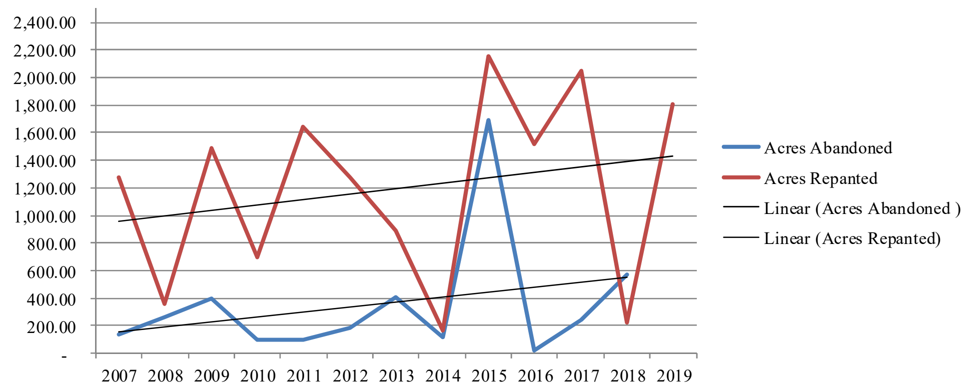
Data kept by the Agricultural Department at Spreckels Sugar (Table 4.1) shows the amount of replanting that has happened each year from 2016 to 2019. It also shows the abandonment or acres lost each year. The data shows that the abandoned acres have increased significantly from 18 acres in 2016 to 569 acres in 2018; replants are also high as well. In Figure 4.2 the amount of abandoned and replanted acres has increased from 2007 to 2018.

Table 4.1: Annual Acreage Replants and Abandonment - Spreckels Sugar, 2016-2019

	2016	2017	2018	2019
Acres Planted	24,682	25,167	24,986	**24,606**
Acres Replanted	1,513	2,049	222	**1,808**
Acres Abandoned	18	238	569	**0**

Source: Agricultural Department Spreckels Sugar Co.

Figure 4.2: Graph of Annual Acreage Replants and Abandonment - Spreckels Sugar, 2016-2019



Source: Agricultural Department Spreckels Sugar Co.

There was 24,986 acers planted in 2018 and five hundred and sixty-nine of those acres were abandoned, this it equates to a 2.2 million dollar loss for the Imperial Valley sugar beet industry. The amount of revenue lost has a significant impact on the local sugar beet industry and could potentially cause it to collapse and no longer exist. It is imperative that the root cause for the replant and abandoned acres be controlled.

4.6.2 Poor Tracking of Crop Diseases

Poor tracking of crop diseases over the years by the use of various electronic files stored in different formats and servers have proven to be a failed method for tracking diseases in sugar beet fields. Poor tracking of crop diseases has led to fields with high disease populations being planted and replanted back to back leading to crop failure. There is no existing method for marking with GPS accuracy when it comes to where disease populations are in a field or for determining how big the population size might be. There is also no existing way to visually track the spread of diseases throughout each agricultural district. Growers have shared sugar beet digging equipment, going from a contaminated field to a non-contaminated field spreading diseases throughout the sugar beet growing district. Not having the proper tools to track diseases in order to avoid it, has affected crop yield and quality, as well as crop loss.

4.6.3 Poor Plant Population

An incorrect method of tracking plant spacing can have significant effects on plant quality and yield. When a sugar beet crop is planted at a much larger spacing than recommended for late and early harvested fields, the summer sun and other field-related issues such as poor seedbed preparations can cause problems. If the grower plants with too wide spacing, the result will be poor emergence leading to a bigger beet, but one with poorer quality. Research shows that a higher tonnage beet will have lower sugar and purity content. There is also new research that indicates much wider spacing can lead to a more active disease infestation and degradation of the crop. Seed spacing is necessary, but can vary according to farming locations and temperatures. The closer the grower is to 100 percent emergence, the better their crop will be if the spacing is appropriate for the growing region.

4.6.4 Poor Agricultural Staff Communications

Data that is unorganized on Excel spreadsheets has led to miscommunication. There is a need for a method in which the agricultural staff can communicate better. All field data collected by each agriculturist needs to be updated to a central location quickly and accurately so that it is available to the entire staff.

4.7 ArcGIS: a Tool for Sugar Beet Crop Data Collection and Crop Loss Analysis.

The term, precision farming, first emerged in the United States in the early 1980s. As the cost of production rises and profit margins shrink, producers and processors of field crops are looking for ways to become more efficient and effective in data collection for the planting and harvesting of products. Today, there are many on-farm tools that help the producer and processor when it comes to on-farm management.

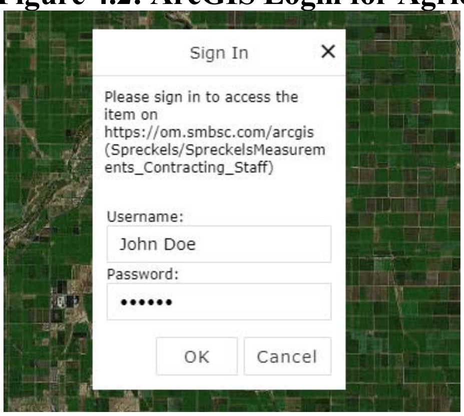
4.8 ArcGIS

After an extensive comparison of software designed to help reduce crop loss, ArcGIS is software created by a company located in Redlands, California, called ESRI Inc. (Environmental Systems Research Institute). "ESRI Inc. was founded to help solve some of the world's most difficult problems. We do so by supporting our users' important work with a commitment to science, sustainability, community, education, research, and positive change" (ESRI 2019). ArcGIS is the world's most powerful tool for mapping and analyzing data. Spreckels Sugar decided to choose ArcGIS created by ESRI Inc. because they are located close to the factory and have user-friendly software. ESRI Inc. also has a great commitment to its customer service as well as integrity when it comes to sustainability and research for technology in agriculture.

4.9 How ArcGIS Works

Collecting, managing, and sharing planting and harvesting information along with disease locations has been made easy by way of accounts that have been set up for each grower. Each grower was given a username and password to their own account and field locations (Figure 4.2). Their individual field locations are visible to them under their user name and password. The entire staff in the Agriculture Department has access to all field locations and information via a master login account.

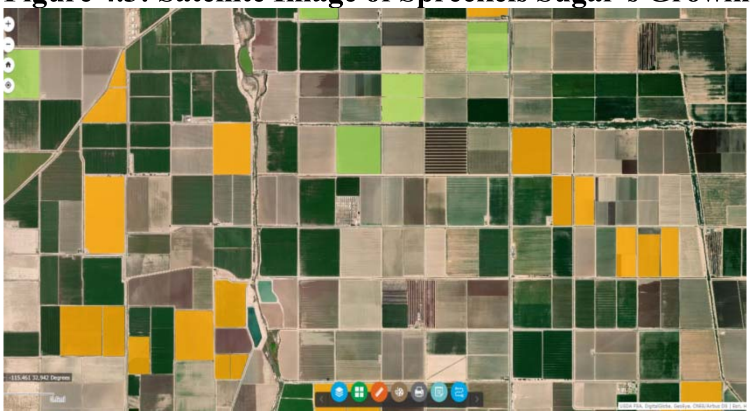
Figure 4.2: ArcGIS Login for Agriculturist and Grower– 2018, 2019 Crop



Source: Shelby Drye

When the grower and agriculturist log into their ESRI account, they will see a satellite image of the growing area that is shared between the two of them. The Agricultural Manager and Agricultural Clerk have access to the same information (Figure 4.3). Each field for the new growing season can be selected on the map. Because there are different growing districts, each field is separated by the colors, light green, orange, and blue. Maps created and data input can be stored from year to year for both the grower and agriculturist to access. As the grower or agriculturist selects a field for the new planting year, the previous year's history for soil type, disease types, and disease population will appear. This helps to keep the grower from selecting a field for use if it is affected by something that could lead to crop loss.

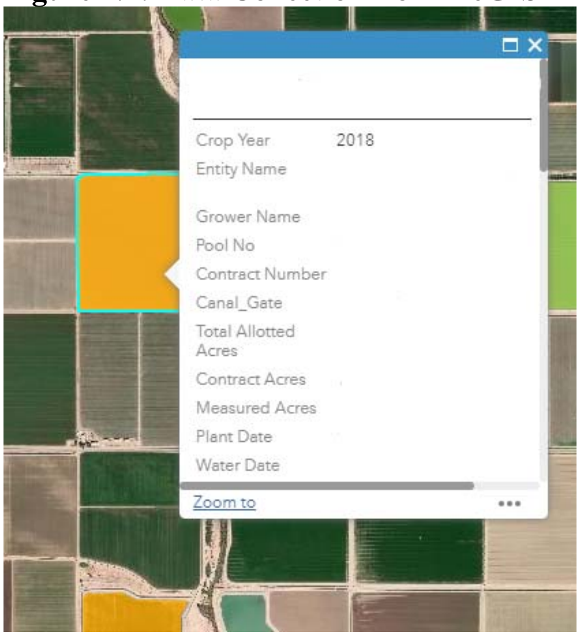
Figure 4.3: Satellite Image of Spreckels Sugar's Growing District – 2018, 2019 Crop



Source: Shelby Drye

Once the map of fields for the growing districts is completed the agricultural staff can go out to growers' fields and collect planting and harvesting data (Figure 4.4). This can be done from any mobile device using ESRI's collector application; if Internet service is not available it can still be collected on the device and uploaded later when service is available. This is a great feature for the much more rural areas found in some growing regions around the world. When the data collection box is open, the grower or agriculturist can manipulate the data by selecting the data box title and then selecting his or her desired input from the drop-down menu. As data is inputted by the agricultural staff or grower, it is collected in a database. The grower or agriculturist can then export the data into an Excel spreadsheet for easy analysis.

Figure 4.4: Data Collection Box ArcGIS– 2018, 2019 Crop



Source: Shelby Drye

After field data is collected, a satellite image using normalized difference vegetation index (NDVI) is taken of each field leading up to harvest and then biweekly throughout the harvesting period (Figure 4.5). This imagery is then used by the growers and agricultural staff to spot areas in fields where the sugar beet crop canopy is under stress. If a grower or agriculturist spots an area in a field that is under stress, he or she can go out to the field to determine the cause of the stress. The grower or agriculturist can then establish a solution to fix what is causing the stress, but if no solution is available, the grower can move the field, or section of field, up in the harvest to take it out before it turns to rot and is abandoned.

Figure 4.5: Normalized Difference Vegetation Index– 2018, 2019 Crop

Source: Shelby Drye

This type of technology has never been available to Spreckels Sugar before. This technology will bring all who are involved with the sugar beet industry in the Imperial Valley together and make collaboration between both producers and processors of sugar beets more effective. By using this technology, the Agricultural staff and growers will be able to collect all field and factory data into one place and will be able to make better decisions concerning crop stress reduction which may later lead to crop loss.

If properly implemented, ArcGIS will give Spreckels Sugar the economic and strategic lead over other industry sugar beet producers and processors. It will create cost savings by creating better on-farm and factory data collection. ArcGIS will also improve communication between the sugar beet grower and processing facility, leading to better decision making when it comes to on-farm management of sugar beet crops. Most importantly, the use of ArcGIS will allow Spreckels Sugar to build a visual framework, one that is based solely off of data, allowing them to track the root cause for sugar beet crop loss as well as lost revenue that follows.

CHAPTER V: ANALYSIS

5.1 Data Collected

Three points of data were collected to complete this thesis. Loss in revenue for the producer (grower cost of producing the crop) and processor (Spreckels Sugar loss of hundredweight of sugar produced), cause of crop loss, and a way to reduce crop loss by using technology.

5.2 Data Collection – Producer (Grower) – Loss in Revenue

Five producers for sugar beets in the Imperial Valley where interviewed to determine the cost per acre for planting one acre of sugar beets. Several things were collected from the producer: Sugar beet seed cost, ground preparation cost, growing period costs, land rent costs, and digging cost as well as subjective costs (Appendix C). Once this was done the total cost for producing one acre of sugar beets was calculated then the Olympic average for five years was taken (Appendix D). The total cost of producing one acre of sugar beets was then multiplied by the amount of acres lost on average over five years (Appendix D) and added to the cost of acres re-planted to produce the average revenue loss to growers annually (Appendix E).

5.3 Data Collection – Processor (Spreckels Sugar) – Loss in Revenue

Five years (2014-2018) of production statistics were collected by way of Spreckels Sugar Company (Appendix F). Several things were obtained: acres planted, tons planted, acres lost, early and late harvest tons per acre, as well as hundredweight of sugar produced and the number of acres re-planted. Once this was done the total cost for profit lost per hundredweight of sugar not produced by Spreckels Sugar was determined by taking the Olympic average for five years (Appendix G).

5.4 Data Collection – Cause of Crop Loss in Sugar Beets

Primary data was multiple years of field research and observation done at the field level. Secondary data collection was research done using various internet search engines, journals, and books.

5.5 Data Collection – Data Collection Tool for Sugar Beet Crop Loss Analysis

Extensive research was done to find the most effective and efficient technology for producers and processors of sugar beets to better manage the sugar beet crop and reduce crop stressors which may later lead to crop loss. This research was done using various internet search engines, articles on the topic, as well as books. Multiple key terms were used in the search for the best data collection system for Spreckels Sugar's 24,500 acres of sugar beets. Terms such as: precision farming, geographical information systems, remote sensing, normalized difference vegetation index, on-farm management tools, crop failure, and others were used in the search for a successful tool. In order to ensure best fit when applying the new method for data collection, thorough interviews were conducted with the agricultural department concerning the current method for data collection at Spreckels Sugar. The result of the interviews established the need for a new, advanced method of data collection.

5.5.1 ArcGIS and Cost of Implementation

A cost analysis was done on the companywide implementation of ArcGIS. Total investment cost would be $26,400 annually to cover grower and company employee accounts (66 accounts). In addition, a one-time charge of $20,000 was budgeted for potential programming costs as well as server upgrades.

5.5.2 Implementation of ArcGIS

A technology committee of twelve local growers was set up for experimentation purposes, along with three agriculturists, one agricultural manager and an agricultural clerk. The ArcGIS system was set up on each one of their smartphones, iPads, and computers. Their fields for the 2018-2019 harvest were then located and marked on the map in preparation to collect data.

5.5.3 Data Collection ArcGIS

Members of the technology committee started to collect, manage, examine, and determine the size of the sugar beet crop, crop health and the potential for crop loss. NDVI for each of the technology committee member's fields was calculated for January, February and March in order to look for any crop stressors in the 2018-2019 sugar beet fields.

5.6 Tools of Analysis

5.6.1 Strategic Fit

"Strategic fit is a situation that occurs when a specific project, target company or product is seen as appropriate with respect to an organization's overall objectives." (Business Dictionary 2019)

5.6.2 Strategic Framework

There are four components of a strategic framework: business objective, approach, measurement, and target. The goal of a strategic framework is to establish a method to show how a project supports the key objectives of stakeholders.

- **Business objective**: Reduce sugar beet acres lost to increase profitability for producers and processors.
- **Approach**: Identify cost of crop loss, cause of crop loss, and then test technology with the Spreckels Sugar agricultural staff and growers that will help reduce crop loss.

- **Measurements**: Measures to ensure the goal of reducing acres lost is being obtained. This will be accomplished by the amount of acre re-plants and abandonment reduced on average over the next five years, and the amount of profit gained by increase in yields over the next five years.
- **Target**: Success will be defined by the reduction in the average amount of acres replanted and abandoned that are affected by controllable crop stressors. Success is met when zero percent crop loss by controllable crop stressors is met.

5.6.3 Key stakeholders of the strategic framework

It is important when analyzing strategic fit to know the key stakeholders. It is the key stakeholders that will ensure the success of the project and meet the projected target.

- **Members of The Agricultural Department**: Agricultural staff, agricultural manager, agricultural clerk and agricultural research group. This group of individuals will be trained on the interworking of the new technology and will be implementing it at the field level.
- **Organization**: Spreckels Sugar Co. will fund the project and directly benefit from the increased profits gained from the reductions of lost acres.
- **Customers**: Producers (Growers) will benefit from the implementation of the new technology as they use it to make better on-farm decisions that will lead to a reduction in acres lost.

5.7 SWOT analysis

There are many strengths and opportunities for the implementation of technology at Spreckels Sugar. Strengths are those attributes and resources that will help Spreckels Sugar meet its mission statement and bring appreciable value to shareholders. The strengths listed above will help Spreckels Sugar have a successful outcome with the execution and establishment of ESRI’s ArcGIS and will aid in the vision of Spreckels sugar to become the preeminent integrated sugar producer in the world. Opportunities are factors that the company can make a profit on or gain an advantage over. ESRI’s ArcGIS will give Spreckels Sugar the advantage of identifying what leads to losses in sugar beet acres and will also allow for better data collection and management.

With every strength and opportunity, there are always weaknesses and threats. Weaknesses are things internally and externally that work against the implementation of ISRIS’s ArcGIS at Spreckels Sugar. Constant delays in the programming of the software, lack of IT support for questions that growers or agricultural staff might have and lack of budgeted funds for further programming of the software are weaknesses that Spreckels Sugar is currently facing.

A much more significant external factor that can jeopardize the implementation and success of ArcGIS are threats. Things that seen as threats by Spreckels Sugar for the success of ArcGIS are Resistance of grower adoption of new technologies and that some growers hate change. Without adoption of the technology by growers, Spreckels Sugar will not achieve its successful implementation of ArcGIS, because so much of its success relies on the grower's input of desired data and information needs.

Figure 5.1: The use of Technology to Reduce Preharvest Losses

Strengths (Internal)	**Weaknesses (Internal)**
• Project aligns with company mission and vision • Appropriate Infrastructure • User-friendly • Set budget for equipment • Low implementation cost • Knowledgeable team • Quick implementation • Good relationship with producers • Reputation for innovation	• Internal competition for budgeted funds • Poor internal communication • Lack of IT support • Need for a larger company server • Resistance of employee adoptions of new technology
Opportunities (External)	**Threats (External)**
• Reduce lost acres of sugar beets • Increase the quality of sugar beets • Increase profits for producers • Reduce cost of crop inputs	• Resistance of grower adoption of new technologies. • Growers having to learn new software technology • Majority of growers hate change • Lack of IT support, from ArcGIS for grower questions

5.8 Further research opportunities

The use of ESRI's ArcGIS for tracking beet digging equipment and creating yield maps for sugar beet fields. Potential to use this technology to generate field maps for variety yield comparison. Research the use of ArcGIS to design maps for variable rate application of chemical's and fertilizers to suppress the spread of sugar beet nematodes and rhizomania and increase yields.

CHAPTER VI: CONCLUSION AND SUMMARY

In this thesis, the topic of sugar beet crop loss and methods for reducing it were explored. The cause and cost of sugar beet crop loss, and the technology used to reduce it was effectively established. A general overview of the sugar beet industry in the Imperial Valley was given, as well as grower practices for planting sugar beets. A brief overview of Spreckels Sugar Company was given along with the responsibilities of the agriculture department for collecting field related data, as well as the new method for data collection using ArcGIS.

Various Excel spreadsheets were put together to determine the amount of profit lost for both the producer and processor for sugar beets that were re-planted or abandoned on the average absolute deviation of five years. Information from these spreadsheets showed that the cost of crop loss is higher for the processor than for the producer. Over a five-year span, from 2014 to 2018, on average 236 acers were lost and 1,261 were re-planted for a total industry revenue loss of $1.1 M. This resulted in a revenue loss of $715,375.21 for the processor and $398,680.05 for the producers to include abandonment and replanting of acres.

Once a loss of revenue was established, the thesis research turned to what was causing the crop failure. The main identifiers of the cause for crop failure were salinity disease, and grower practices. Salinity caused damage to the health of the seed and in some cases did not even allow for the seed to germinate. Nematodes stunted or stopped the growth of the sugar beet all together, making it weaker and more susceptible to late harvest rots. The same was found for rhizomania. The biggest factor in crop loss was grower practices and the lack of data collection to make smarter decisions such as which fields to place a crop in to avoid crop stressors altogether. Growers had no way of tracking diseases or even looking back at previously planted fields to see if they had been affected in prior planting seasons.

For this reason, a new technology platform called ArcGIS was set up by Spreckels Sugar to collect, manage, examine and determine crop health prior to the start of harvest, so that the many crop stressors which sugar beets face could be reduced. This software platform would not exceed $26,000 annually along with an additional one-time charge of $20,000 to set up. The return on investment (ROI) would be the return in revenue gained each year by processing a larger portion of the crop that would usually be abandoned to rot. Both the producers and processor were excited about the establishment of ArcGIS as it proved worthy of catching potential crop stressors which would later lead to rot. The establishment of ArcGIS opened up communication between the producer and processor at the field level, allowing for more minds to work together to reduce crop loss and gain back lost revenue.

REFERENCES

Batte, Marvin T., and Michael W. Arnhold.09 25, 2002. https://www.sciencedirect.com/science/article/pii/S0168169902001436 (accessed 10 29, 2018).

Business Dictionary . 02 10, 2019. http://www.businessdictionary.com/definition/strategic-fit.html (accessed 03 14, 2019).

Cattanach, A. W., A. G. Dexter, and E. S. Oplinger. *Horticulture and Landscape Architecture.* 10 26, 2018. https://hort.purdue.edu/newcrop/afcm/sugarbeet.html (accessed 10 26, 2018).

Coons, George H. *Organic Roots Collection* . 1953. https://naldc.nal.usda.gov/download/IND43894371/PDF.

ESRI. *Who We Are.* 01 10, 2019. https://www.esri.com/en-us/about/about-esri/who-we-are (accessed 02 11, 2019).

Gallian, J., and Oliver T. Neher. *University of Idaho.* 02 2014. https://www.cals.uidaho.edu/edcomm/pdf/PNW/PNW657.pdf (accessed 11 01, 2018).

Griffin, Terry W. "Big Data Considerations for Rural." *Journal of The ASFMRA*, 2016: 14.

Grisso, Robert, Mark Alley, Phil McClellan, Dan Brann, and Steve Donohue. 2009. http://farmerslibrary.net/wp-content/uploads/2016/06/PrecisionFarming-AComprehensiveApproach.pdf (accessed 10 29, 2018).

Hillnhutter, C., A. K. Mahlein, R. A. Sikora, and E. C. Oerke. 02 16, 2011. https://www.sciencedirect.com/science/article/pii/S0378429011000566 (accessed 10 30, 2018).

Janseen, Sander J.C., and Charyl H. Potor. *Elsevier.* 11 21, 2017. https://www.sciencedirect.com/science/article/pii/S0308521X16305637?openEntitledRecommendationsModal=true (accessed 01 17, 2019).

Mahmood, Salar A., and Alistair J. Murdoch. 09 05, 2017. https://www.sciencedirect.com/science/article/pii/S1161030117300679.

Meister, Herman S. *UCDAVIS.* 08 2004. https://coststudyfiles.ucdavis.edu/uploads/cs_public/67/54/67547b20-6a44-4741-8a90-e274d61d6260/sugarbeet04.pdf (accessed 11 01, 2018).

Ortiz, Carlos, and Jolene Dessert. *Imperial County*. 07 10, 2018. http://www.co.imperial.ca.us/ag/docs/spc/crop_reports/2017_Imperial_County_Crop_and_Livestock_Report.pdf (accessed 11 01, 2018).

Oudemans , Peter V., Larisa Pozdnyakova, Faiz Rahman, and Marulyn G. Hughes. 09 3, 2002. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2620566/pdf/207.pdf (accessed 10 29, 2018).

Smith, Haddock, Alexander Downie, and Easton Jesnsen. *The Influence of Cultural Practices On the Quality of Sugar Beets*. 05 12, 1958. https://www.bsdf-assbt.org/jsbr/volume-10-1958/jsbrvol10no4p290to301theinfluenceofculturalpracticesonthequalityofsugarbeets/.

Soomro, and Tariq Rahim. *OMICS Ebooks Group*. 2 12, 2015. https://www.esciencecentral.org/ebooks/ebookdetail/smart-agriculture-an-approach-towards-better-agriculture-management (accessed 1 17, 2019).

Spreckels. 06 23, 2018 at 4:30PM. http://www.spreckelssugar.com/default.aspx.

Spurlock, Terry N., Craig S. Rothrock, Scott W. Monfort, and Terry W. Griffin. "The distribution and colonization of soybean by Rhizoctonia solani AG 11 in fields rotated with rice." *Soil Biology & Biochemistry*, 2016: 8.

United States Department of Agriculture . 11 02, 2018. https://www.ers.usda.gov/data-products/sugar-and-sweeteners-yearbook-tables.aspx (accessed 11 13, 2018).

Welte, J., A. Ault, C. Bowman, A. Layton, J. Krogmeier, and D. Buckmaster. 06 27, 2013. http://www.cigr.org/Proceedings/uploads/2013/0392.pdf (accessed 10 31, 2018).

APPENDIX A

Sugar Beet Processing Factories in The United States

Spreckels Sugar Company Factory
Wholly owned subsidiary of Southern Minnesota Beet Sugar Cooperative
Brawley, CA . . . . Est. 1947-48 . . . . Slicing 10,000 tons/day

Amalgamated Sugar Company Factories
Mini-Cassia, ID . . . . . . Est. 1917 . . . . Slicing 17,500 tons/day
Nampa, ID . . . . Est. 1942 . . . . Slicing 12,000 tons/day
Twin Falls, ID . . . . Est. 1916 . . . . Slicing 6,800 tons/day

Michigan Sugar Company Factories
Bay City, MI . . . . Est. 1901 . . . . Slicing 8,700 tons/day
Caro, MI . . . . Est. 1899 . . . . Slicing 3,800 tons/day
Croswell, MI . . . . Est. 1902 . . . . Slicing 4,000 tons/day
Sebewaing, MI . . . . Est. 1902 . . . . Slicing 5,500 tons/day

Minn-Dak Farmers Cooperative Factory
Wahpeton, ND . . . . Est. 1974 . . . . Slicing 9,300 tons/day

American Crystal Sugar Company Factories
Crookston, MN . . . . Est. 1954 . . . . Slicing 5,900 tons/day
East Grand Forks, MN Est. 1926 . . . . Slicing 9,200 tons/day
Moorhead, MN . . . . . . Est. 1948 . . . . Slicing 5,900 tons/day
Drayton, ND . . . . Est. 1965 . . . . Slicing 6,700 tons/day
Hillsboro, ND . . . . Est. 1974 . . . . Slicing 9,000 tons/day

Southern Minnesota Beet Sugar Cooperative
Factory
Renville, MN . . . . Est. 1975 . . . . Slicing 17,500 tons/day

Sidney Sugars, Inc. Factory*
*Wholly owned subsidiary of American Crystal Sugar Company
Sidney, MT . . . . Est. 1925 . . . . Slicing 6,275 tons/day

Western Sugar Cooperative Factories
Fort Morgan, CO . . . . Est: 1906 . . . . Slicing 5,820 tons/day
Billings, MT . . . . Est. 1906 . . . . Slicing 5,000 tons/day
Scottsbluff, NE . . . . Est. 1910 . . . . Slicing 5,000 tons/day
Lovell, WY . . . . Est. 1916 . . . . Slicing 3,000 tons/day
Torrington, WY . . . . . . Est. 1926 . . . . Slicing 5,500 tons/day

Wyoming Sugar Cooperative Factory
Worland, WY . . . . Est. 1916 . . . . Slicing 3,600 tons/day

APPENDIX B

Sugar Beet Production Amounts for processing locations in The United States

CALIFORNIA
Acres Harvested 24,500
Total Tons 1,078,000
Yield (tons per acre) 44
Percent of U.S. Production . . . 3

COLORADO
Acres Harvested 29,700
Total Tons 944,000
Yield (tons per acre) 31.8
Percent of U.S. Production . 2.6

IDAHO
Acres Harvested 182,000
Total Tons 6,425,000
Yield (tons per acre) 35.3
Percent of U.S. Production . 18.2

MICHIGAN
Acres Harvested 153,000
Total Tons 4,437,000
Yield (tons per acre) 29.0
Percent of U.S. Production . 12.5

MINNESOTA
Acres Harvested 463,000
Total Tons 12,270,000
Yield (tons per acre) 26.5
Percent of U.S. Production . 34.8

MONTANA
Acres Harvested 45,800
Total Tons 1,292,000
Yield (tons per acre) 28.2
Percent of U.S. Production . 3.6

NEBRASKA
Acres Harvested 48,900
Total Tons 1,457,000
Yield (tons per acre) 29.8
Percent of U.S. Production . 4.1

NORTH DAKOTA
Acres Harvested 215,000
Total Tons 6,020,000
Yield (tons per acre) 28
Percent of U.S. Production . . 17

OREGON
Acres Harvested 11,000
Total Tons 418,000
Yield (tons per acre) 38
Percent of U.S. Production . 1.1

WYOMING
Acres Harvested 31,300
Total Tons 895,000
Yield (tons per acre) 28.6
Percent of U.S. Production . 2.5

APPENDIX C

Grower Cost per Acre of Sugar Beet production – Estimated Cost - 2019

Sugar Beet Seed	Seed Unit Q	Rate	Cost per Acre/ Per Unit
Seed	1	$167	$167
Tech Fee	1	$148	$148
Total Sugar Beet Seed Cost			**$315.00**

			Materials		*Hand Labor*		
Ground Preparation	**Quantity**	**Prevailing Rate**	**Type**	**Cost**	**Items/Hours**	**Dollars**	**Cost per Acre**
Stubble Disc	1	$ 28.00					28.00
Subsoil 2nd Gear	1	$ 65.00					65.00
Corrugate	1	$ 22.00					22.00
Flood	1		Water 1.0 ac-ft.	$ 22.00	1	$ 12.00	34.00
Fertilizer	1	$ 8.00	250 lb. 11-52-0	$ 37.50	1		45.50
Triplane	1	$ 26.00					26.00
List	1	$ 35.00					35.00
Pre-irrigate beds	1		Water 18 ac-ft.	$ 22.00	3	$12.00	58.00
Lilliston beds	1	$ 14.00					14.00
Total Ground Preparation Costs							**$327.50**

Growing Period							
Plant	1	$ 17.00	Seed 3.0" spacing	$ 52.00	1		69.00
inject Insecticide	1	$ 25.00	Admire/Lorsban	$ 18.00	1		43.00
Herbicide ground	3	$ 12.50	Herbicide	$ 75.00	1		112.50
Cultivate	2	$ 16.00					32.00
Fertilize (dry)	2	$ 17.00	160 lb. N(am-nitrate)	$ 68.80	1		102.80
Insecticide	4	$ 8.50	insecticide	$ 80.00	1		114.00
Disease control grd	2	$ 12.50	Fungicide (sulfur)	$ 8.00	1		33.00
Crop Irrigation / Pre-Irrigation (Per Acre)	1		Water 18 ac-ft.	$ 22.00	3	$ 12.00	58.00
Work ends	2	$ 12.00					24.00
Total Growing Period Costs							**$588.30**
Ground Preparation, Growing Period Costs							**$915.80**

Digging Costs			**Cost per Acre**
Digging	2.65	$42.00	111.30
Hauling	2.50	$42.00	105.00
Chopping	1.00	$14.75	14.75
Total Digging Costs			**$231.05**
Ground Preparation, Growing Period, Land Rent, Digging Cost			**$1,497**

Sugar Beet Seed, Ground Preparation, Growing Period, Land Rent, Digging Cost	**$1,812**

Subjective Costs	**Quantity**	**Rate**	**Cost per Acre**
Sprinklers (Own) (Per Acre)	1	$165.00	$165.00
Sprinklers (Rent) (Per Acre)	1	$410.00	$410.00
Labor Crew (Rotten Beet Removal) Per Person/Per hour	1	$16.00	$16.00
Soil Sampling Cost (Per Acre)	1	$20.00	$20.00
PCA Pest Control Adviser (Cost Per Acre)	1	$20.00	$20.00
Total Subjective Costs (Owning Sprinklers)			**$221**
Total Subjective Costs (Renting Sprinklers)			**$466**

Total Everything (Owning Sprinklers)	**$2,033**
Total Everything (Renting Sprinklers)	**$2,278**

Source: Spreckels Sugar –Shelby Drye

APPENDIX D

Producer Loss

Year	Acres Planted	Tons Planted	Acres Harvested	Acre Loss	Ton Loss	Early Harvest TPA	Late Harvest TPA	Producer Cost Per Acre	Cost of Lost Acres	Potential Revenue (Loss)	% Sugar	% Purity
2014	24,411	732,330	24,291	120	5,210	30	43	$ 2,033	$ 243,960	$ 209,616	16.77%	90.08%
2015	24,178	725,340	22,484	1,694	73,892	30	44	$ 2,033	$ 3,443,902	$ 2,969,045	16.97%	89.28%
2016	24,682	740,460	24,664	18	806	30	45	$ 2,033	$ 36,594	$ 31,113	16.39%	89.14%
2017	25,167	755,010	24,929	238	10,727	30	45	$ 2,033	$ 483,854	$ 429,235	16.90%	89.29%
2018	24,986	749,580	24,417	569	24,882	30	44	$ 2,033	$ 1,156,777	$ 982,211	16.71%	89.19%
Total	123,424	3,702,720	120,785	2,639	115,517	150	220.59	$ 10,165.00	$ 5,365,087	$ 4,621,220	84%	447%
Average	24,685	740,544	24,157	528	23,103	30	44.12	$ 2,033.00	$ 1,073,017	$ 924,244	17%	89%
Oympic Average	**24,693**	**740,790**	**24,457.33**	**236**	**13,606**	**30**	**44**	**$ 2,033**	**$ 628,197.00**	**$ 540,354.02**	**17%**	**89%**
	Projection Amount			Short Fall				Short Fall				

APPENDIX E

Revenue Loss Calculated 2014-2018 (Producer)

Baseline (Projection)		
Current NSP	$	0.24
% Purity of Beets Harvested		89.19
% Sugar in Beets Harvested		17.00
Price per ton	$	40.19
Net tons		740,790
Total YTD beet pmt by contract	$	29,773,851.09

Model (Short Fall) (Loss)		
Current NSP		0.24
% Purity of Beets Harvested		89.19
% Sugar in Beets Harvested		17.00
Price per ton		40.19
Net tons		13,606.48
Total YTD beet pmt by contract	$	546,871.87

Difference in Projection and Short fall	
Current NSP	-
% Purity of Beets Harvested	0.00
% Sugar in Beets Harvested	-
Price per ton	-
Net tons	727,184
Total YTD beet pmt by contract	29,226,979.22

Output		
YTD Beet pmt (Baseline)	$	29,773,851.09
YTD Beet pmt (Model) (Loss)	$	546,871.87
Model Less Baseline	$	29,226,979.22
Producers loss (Sale of sugar beet)	**$**	**546,871.87**
Producers loss (Growing Exp)	**$**	**426,992.65**
R-plant cost	**$**	**1,019,535.73**
Total Loss	**$**	**1,993,400.25**

Conclusion

Year	**Revenue Lost Over Five Years**	
2014	$	398,680.05
2015	$	398,680.05
2016	$	398,680.05
2017	$	398,680.05
2018	$	398,680.05
Total	$	1,993,400.25
Average	$	398,680.05
Average Absolute Deviation	**$**	**398,680.05**
	Growers	

APPENDIX F

Processor / Producer / Re-plant Loss

Year	Acres Planted	Acres Harvested	Acre Loss	Re-Plant	Spreckels Loss Per Acre (Seed Cost)	Gorwers Loss Per Acre (Seed Cost / Land Prep)	Spreckels Loss / Re-plant * Loss	Gorwers Loss / Re-plant * loss
2014	24,411	24,291	120	162	$ 110.00	$808.30	$ 17,820.00	$ 130,944.60
2015	24,178	22,484	1,694	2,155	$ 110.00	$808.30	$ 237,050.00	$ 1,741,886.50
2016	24,682	24,664	18	1,513	$ 110.00	$808.30	$ 166,430.00	$ 1,222,957.90
2017	25,167	24,929	238	2,049	$ 110.00	$808.30	$ 225,390.00	$ 1,656,206.70
2018	24,986	24,417	569	222	$ 110.00	$808.30	$ 24,420.00	$ 179,442.60
Total	123,424	120,785	2,639	6,101	$ 550.00	$4,041.50	$ 671,110.00	$ 4,931,438.30
Average	24,685	24,157	528	1,220	$ 110.00	$808.30	$ 134,222.00	$ 986,287.66
Average Absolute Deviation	**24,693**	**24,457.33**	**236**	**1,261.33**	**110.00**	**808.30**	**138,746.67**	**1,019,535.73**
	Projection Amount		Short Fall					

APPENDIX G

Revenue Loss Calculated 2014-2018 (Processor)

Baseline (Projection)		
Acres		24,693.00
TPA		30
Tons		740,790
Yield		2.27
CWT		1,679,124.00
Profit Margin	$	3.00

Model (Short Fall)		
Acres		24,457
TPA		44
Tons		1,076,937.91
Yield		2.62
CWT		2,825,167.12
Profit Margin	$	3.00

Difference in Projection and Short fall		
Acres		236
TPA		14
Tons		336,148
Yield		0.36
CWT		1,146,043
Profit Margin		-

Output		
CWT Produced (Baseline)		2,825,167
CWT Produced (Model)		1,679,124
Model Less Baseline		1,146,043
Profit Times CTW (profit $ 3.00)	**$**	**3,438,129.36**
Re-plant cost	**$**	**138,746.67**
Total Loss	**$**	**3,576,876.03**

Conclusion

Year		**Revenue Lost Over Five Years**
2014	$	715,375.21
2015	$	715,375.21
2016	$	715,375.21
2017	$	715,375.21
2018	$	715,375.21
Total	$	3,576,876.03
Average	$	715,375.21
Average Absolute Deviation	**$**	**715,375.21**
		Spreckels sugar