WATER USE AND THE REGIONAL ECONOMIC IMPACT OF THE COTTON INDUSTRY ON THE SOUTHERN OGALLALA AQUIFER

by

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ABSTRACT

The Ogallala Aquifer is one of the largest freshwater aquifers in the world underlying eight contiguous states in the Great Plains Region of the United States. Recharge of the aquifer is reliant on precipitation, which is an insufficient condition for the southern portion of the region. The Southern Ogallala Region rose to prosperity with the advent of irrigation techniques allowing for irrigation of four primary crops: corn, cotton, sorghum, and wheat. Faced with an ever-decreasing water table, policymakers are under increased pressure to implement water conservation policies aimed at managing the decline of the aquifer in hopes of extending its usable life and maintaining the economy of the region.

This study evaluates the economic contribution of the cotton industry to the Southern Ogallala Region and its subsequent water use with the objective of determining how this industry affects both the economy of the region and the valuation of water. Cotton has been an important component of this region for over 150 years and boasts specific characteristics that make it highly suitable for the climate of this region. In addition to evaluating the cotton industry, this study also incorporates an in-depth analysis of the valuation of water, sustainable agriculture, and production scenarios that may become prevalent in future conditions when irrigation is a limited option.

In 2014, 3.8 million acres of cotton were planted in the Southern Ogallala Region; 2.2 million acres of dryland and 1.6 million acres of irrigated. The irrigated acres planted produced 1.1 billion pounds of cotton lint and over 800,000 tons of cottonseed. It was estimated that approximately 903,708 acre-feet of irrigation was applied to for this level of production. The total direct sales of dryland and irrigated cotton production and processing totaled $1.7 billion dollars.

The agricultural industries of the Southern Ogallala Region are closely interconnected and the subsequent ripple effects of cotton production on other related industries were estimated to determine the economic contribution of the cotton industry to the region. The cotton industry, including production and processing, contributed over $3.3 billion dollars to the Southern Ogallala Region's economy in 2014 and supported over 26,000 jobs.

An important focus of this study was to evaluate the cotton industry in terms of the value of water used. The regional economic value of irrigated cotton production was $2,145 per acre-foot and the regional economic value of irrigated cotton production and processing was $2,525 per acre-foot of water applied.

The economy of the Southern Ogallala Region is reliant on agricultural commodities. A change in the production of one agricultural industry will affect other industries, and subsequently, the livelihood of the region. To promote the economic continuance of the region, effective water policies must be implemented that consider the interconnection of these industries as well as the most efficient allocation of water. This study's evaluation of the cotton industry will assist in providing a foundation for policymakers when considering and implementing future water polices.

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CHAPTER ONE

INTRODUCTION

The Great Plains is one of the most productive agricultural areas in the United States. This region supplies a significant portion of the nation's commodity crops including wheat, corn, cotton, and sorghum, and supports an expansive livestock industry. Consequently, agribusiness is a critical economic driving force behind the continued profitability and development of this region. The Great Plains contains one fifth of all United States' cropland and the agricultural commodities produced are a vital part of the local, regional, and national economy (Guru & Horne, 2000).

In order to produce yields capable of supporting a nation, in a region where farmers are increasingly at the mercy of climate, agricultural producers in the Great Plains region turned to irrigation technology to compensate for variable rainfall. By utilizing irrigation, producers are able to generate more than three times the production value of dryland acreage annually (Bian, 2015). Due to low precipitation rates in most of this region, most agricultural producers are dependent on the Ogallala Aquifer to support their water needs. Intense irrigation practices combined with the variability in saturated thickness of the aquifer across the region has led to a lack of groundwater underlying certain sections of this region. In those areas with low precipitation, and therefore low recharge rates, irrigation has become more costly due to a decrease in well yields and an increase in pumping costs.

The following subsections provide a general overview of the region overlying the Ogallala Aquifer. They begin with early settlement of the Great Plains, followed by a discussion of the development of irrigation practices, continue on to a brief synopsis of the characteristics of the commodity markets in the Southern Ogallala Region, and conclude with the significance and objectives of the study.

1.1 Settlement of the Great Plains

Initial settlement of the Great Plains was a result of three main factors; the Homestead Act of 1862, overpopulation in cities on the eastern seaboard, and the introduction of the transcontinental railroad. The Homestead Act was designed to encourage westward migration by granting settlers 160 acres of public land, which would become the settlers' private land if one of two conditions were met. First, after six months on the homestead, the settler could purchase the land from the government. Second, after five consecutive years on the homestead, and a small filing fee, the land would automatically be transferred over to private ownership. In this way, the United States government was able to partition out over 80 million acres of public land by 1900 and ultimately paved the way for the Great Plains to become an agriculture hub for the United States. The Homestead Act, in part, was fueled by the high unemployment rate and overpopulation experienced in large cities during the mid-1800s prompting many head of households to try their luck farming. With high rates of Irish immigrants traveling to the eastern seaboard, savvy business owners realized the wealth of opportunity that could be gained from hiring inexpensive labor and selling their wares to settlers in the Western portion of the country and pushed for the Homestead Act to be sanctioned (Homestead Act, 2015).

The sixty years after the Homestead Act was enacted, immense ecological changes were realized in the Great Plains region as the land was tilled to create viable cropland. During this process, the native grasses of the Plains were uprooted causing irreversible damage to the land. These grasses were essential for preventing soil erosion and their destruction played a significant role in the detrimental effects of the Dust Bowl that would sweep the Great Plains.

The early 1900s proved profitable for agriculture in the region because of several factors: a land boom generated from rising wheat prices, the First World War, years of higher than normal precipitation rates, and generous farm policies. These conditions attracted farmers who flocked to the Great Plains to take advantage of the economic opportunities. The increase in farmers caused a direct increase in the number of grassland acres being converted to cropland; however, a decrease in wheat prices along with the negative economic effects associated with the Great Depression caused many agricultural producers in the Great Plains to abandon their farms, leaving thousands of acres of exposed topsoil. In addition to the devastating economic effects of the Great Depression, an eight-year drought settled into the region; another factor in the migration of farmers out of the Great Plains. This drought marked the beginning of the Dust Bowl, which further contributed to the economic downward spiral brought on by the Depression and led to ecological damage of the Great Plains, destroying an estimated 5.4 million acres of viable cropland. The severity of the Dust Bowl can be demonstrated in the fact that an estimated 850 million tons of topsoil, previously rooted into place by native grasses, were blown away in 1935 alone (Walker, 2015).

1.2 Development of Irrigation in the Great Plains

While the Great Depression and the Dust Bowl brought devastation, their end signaled a new agricultural era, influenced by the technology developed during World War II. Prior to World War II, irrigation technology was limited to windmills that allowed farmers and ranchers to reach groundwater within 30 feet of the surface. The water that could be drawn using windmills was enough to irrigate 5 acres or provide water for 30 cattle (Cunfer, 2005). After World War II, technology was improved with the advent of new pumps developed in the oil industry and powered by low-cost automobile engines (Hornbeck, 2011). In addition to more powerful pumps, center pivot sprinklers were developed, allowing farmers to irrigate their crops more efficiently (Guru & Horne, 2000). Center pivot technology, invented by a farmer in Colorado, was adopted throughout the Great Plains as it was "particularly suited to the Great Plains: able to direct water to plants with minimal evaporation in dry windy weather and able to accommodate large fields" (Hornbeck & Keskin, 2011). Center pivot technology, in combination with increased power of well pumps, aided in the increased use of groundwater beginning in the late 1940s. It was not long before the groundwater extraction rate far exceeded the Ogallala Aquifer's natural rate of recharge. The United States Geological Survey has estimated that the withdrawal rate of the Aquifer quintupled from 1949 to 1974 resulting in a substantial decline in the water table (McGuire et al., 2000).

During the mid-1900s, farmers had little inclination to monitor groundwater consumption as they believed the aquifer was an inexhaustible resource. This view of groundwater availability, combined with a growth in irrigation technology, created a positive impact on both crop yield and crop quality. The economy of the region was stimulated as farm production sales encouraged population growth, employment, and total income, promoting the Great Plains region into a prominent position as an important producer of agricultural commodities in the country. The vast amount of water pumped from the Ogallala Aquifer due to increased technology can be demonstrated by the number of irrigation wells in the 1950s versus the 1940s. Irrigation wells totaled 8,346 in 1948 and increased to 55,000 only ten years later supporting over 3,884,766 acres of irrigated cropland (Terrell, 1998).[1] Driven mainly by financial motives, agricultural producers in the region extracted an ever-increasing amount of groundwater; from 480 million cubic feet of groundwater in the 1950s to 2,150 million cubic feet in 1980 (Alley et al., 1999). By 1977, one of the poorest farming regions in the United States had been transformed into one of the wealthiest by raising much of the country's agricultural exports and fed beef (Little, 2009).

[1] In 2011, the number of irrigation wells were estimated at over 200,000 supporting over 16 million acres of irrigated cropland (University of Nebraska-Lincoln, 2011).

Allen et al. (2007) tracked the progression of water consumption by agricultural commodities and provided scenarios for future water use. The progression encompasses the following six events:

1. Wasteful water consumption practices when the Ogallala Aquifer was considered to be an inexhaustible source,
2. Development of highly efficient irrigation systems that failed to reduce total water withdrawn due to continued drilling of irrigation wells,
3. Emphasis on crop genetics and management strategies aimed at increasing water use efficiency,
4. Development of crop rotations and integrated crop-livestock systems aimed at reducing overall water use,
5. Inclusion of sufficient dryland acreage to offset groundwater withdrawals,
6. A return to a larger incorporation of dryland systems.

It is thought that the region is operating somewhere between stages three and six and this assumption will provide the basis for the remainder of this study.

1.3 Background on the Ogallala Aquifer Region, with an emphasis on the Southern Ogallala Region

The Ogallala Aquifer underlies eight contiguous states, stretching from South Dakota to Texas. Covering over 174,000 square miles, it is one of the largest freshwater aquifers in the world. The aquifer's saturated thickness ranges from over 1,300 feet in parts of Nebraska to less than a foot in parts of Texas, with an overall average of 200 feet. Today, over 90 percent of groundwater extraction is for the production of agricultural commodities; however, the aquifer also provides water in support of the increasing population of the Great Plains region (Amosson et al., 2014). Once viewed as an inexhaustible resource, the heavy use of the Ogallala Aquifer has caused a substantial decrease in the water table, as the rate of recharge back to the aquifer is significantly lower than the rate of withdrawal. This unbalance is cause for concern as rates of recharge have been recorded to be as low as 0.024 inches per year in the Southern High Plains of Texas due to infrequent rainfall (Ryder, 1996). Lack of annual precipitation in much of the region creates a shortage of surface water, resulting in the reliance on the aquifer to support industrial, municipal, and agricultural water needs.

The southern portion of the Ogallala Region, as shown in Figure 1, encompasses 97,000 square miles underlying parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas.

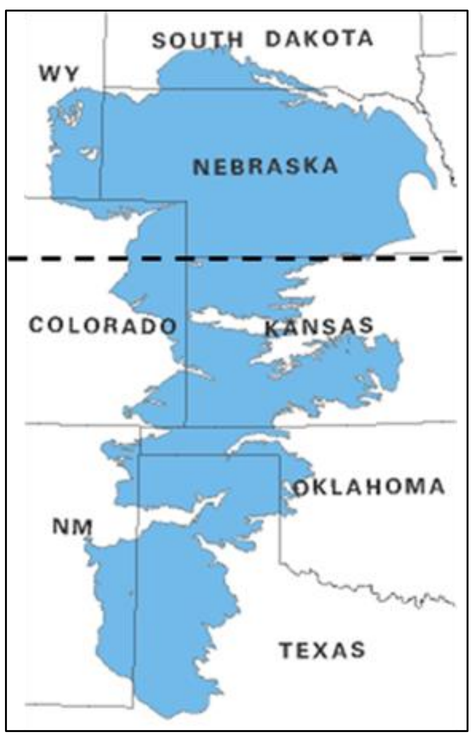

Figure 1. Southern Ogallala Region (shaded area below dashed line)

The region's semi-arid climate and low precipitation rates require the majority, if not all, irrigated agricultural producers in the Southern Ogallala Region to rely almost exclusively on the aquifer for their water needs (Guerrero et al., 2010). Despite less than desirable climactic conditions, the Southern Ogallala Region is one of the most productive agricultural regions of the United States supporting cash crops such as corn, wheat, cotton, and sorghum, as well as a prominent livestock industry.

The Southern Ogallala Region consists of 19.8 million acres of cropland divided into 12.6 million acres of dryland and 7.2 million acres of irrigated (Figure 2). The major dryland crops and their respective acreage planted in 2014 were:

- Wheat – 7 million acres
- Cotton – 2.3 million acres
- Sorghum – 2.3 million acres
- Corn – 1 million acres

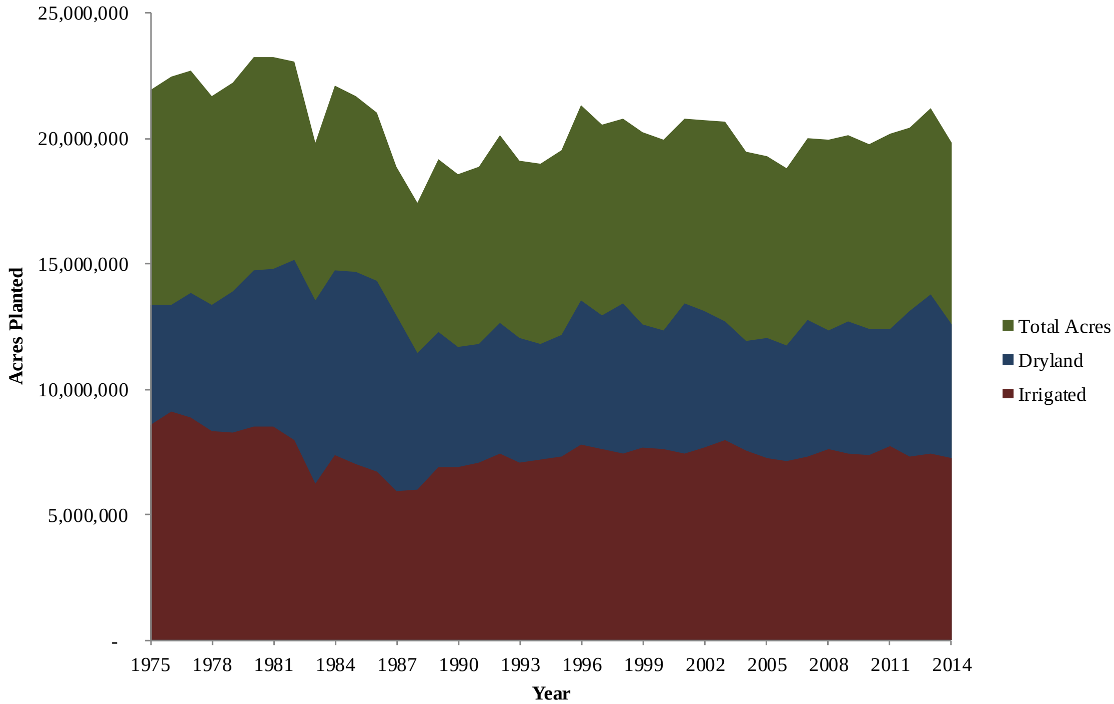

Figure 2. Southern Ogallala Region irrigated and dryland crop acres, 1975-2014.

Although wheat acreage has decreased from a high of 10 million dryland acres planted from 1980 to 1986, it remains the dominant crop in terms of dryland acreage and accounts for 7 million acres or 55 percent of the total dryland acreage planted in the study region in 2014. Dryland cotton acres planted rank second with 2.3 million acres planted or 18 percent of the dryland acreage in 2014.

The major irrigated crops and their respective acreage planted in 2014 were (Figure 3):

- Corn – 2.6 million acres
- Wheat – 1.7 million acres
- Cotton – 1.6 million acres
- Sorghum – 0.7 million acres

- Other – 0.6 million acres[2]

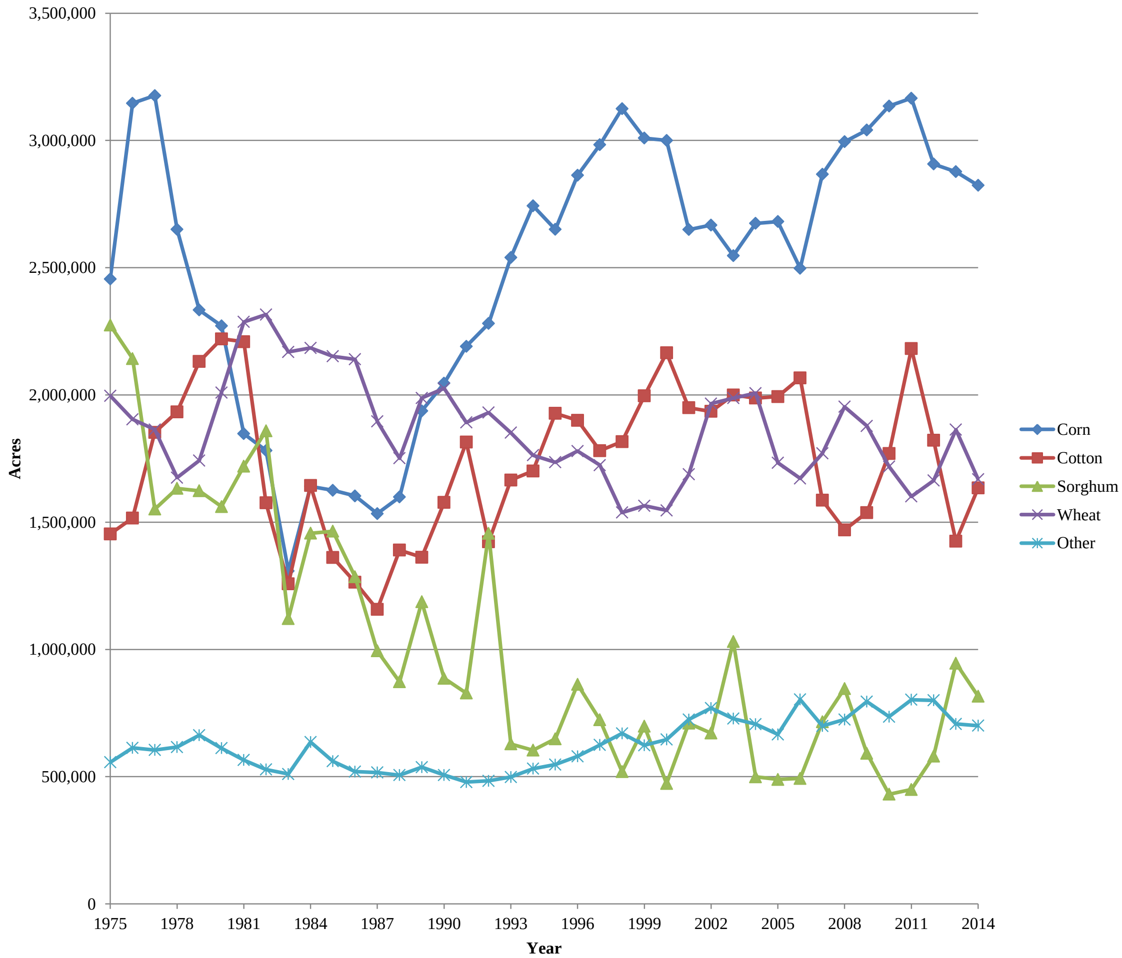

Figure 3. Irrigated acreage by crop in the Southern Ogallala Region, 1975-2014.

Irrigated corn has remained the primary irrigated crop in terms of acres planted for the past decade, averaging 2.6 million acres over this period. The beginning of the biofuel era resulted in agricultural producers diverting irrigated acreage to the production of corn and decreasing acreage dedicated to cotton and other irrigated crops. Demand from both livestock and ethanol plants for corn and other feed grains has kept the acreage

[2] Other irrigated crops include alfalfa, corn silage, and sorghum silage.

associated with these crops high as they were relatively profitable. For example, due to high demand and short supply, corn produced in the Southern Ogallala Region receives as much as 50 cents more per bushel than corn produced in the Midwest (Amosson et al., 2014).

Corn, wheat, and cotton are the three major irrigated crops in the region. Irrigated cotton ranks third at 1.6 million acres planted or 22 percent of the total irrigated acreage in 2014, closely following wheat (1.7 million acres). Total cotton acreage represents 3.9 million acres or 20 percent of the study region and 36 percent of the total cotton acreage planted nationally in 2014.

In addition to crop production, the Southern Ogallala Region is home to a significant portion of the national livestock industry (Figure 4). Livestock operations, mainly beef cattle, are spread throughout the region, however it is the Texas High Plains that has earned the title of "cattle feeding capital of the world" and supports 85 percent of the state's fed beef (Almas, 2004).

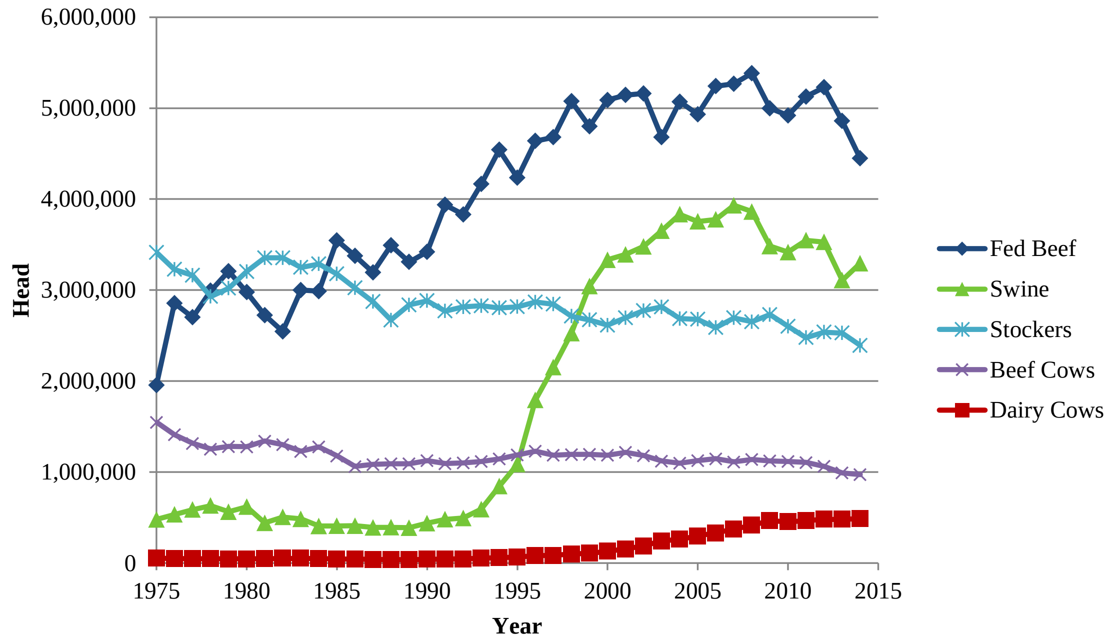

Figure 4. Livestock Inventory in the Southern Ogallala Region, 1975-2010.

The 2014 livestock inventories for the region are:

- Cattle on Feed – 4,308,607 head
- Hogs – 2,970,107 head[3]
- Total Stockers – 2,392,388 head[4]
- Beef Cows – 973,547 head
- Dairy – 488,059 head

The favorable conditions that allowed the success of the cattle industry attracted the swine and dairy industries to the region. The expansion of the livestock industry created a greater reliance on groundwater to meet the increased demand for animal feed

[3] Hogs include breeding, nursing, and finishing
[4] Stockers include summer and winter

(Almas et al., 2015). Guerrero, Amosson, and McCollum (2013) have indicated that an expansion of the livestock industry, mainly beef operations would have a minimal effect on water resources. This minimal effect is reflected in cow-calf and stocker operations where livestock graze dryland pasture or wheat acreage resulting in less direct and indirect water use than feedlot operations, which rely almost exclusively on feed grains for nutritional support of their livestock. Feed grains require high amounts of water to produce resulting in feedlots overall water use to be substantially higher than grazing operations. An increase in economic activity associated with livestock expansion, especially cow-calf and stocker operations, could help mitigate future losses from shifting irrigated production to dryland as the aquifer depletes.

1.4 Significance of the Study

This study focuses on the economic contribution of the cotton industry to the Southern Ogallala Region and its subsequent water use. Upland cotton is an important commodity to focus on as it is one of the four primary crops produced in this region and continues to contribute significantly to the regional economy. As outlined in subsection 1.3, cotton acreage accounted for 20 percent of the acres planted in the region in 2014. While only 42 percent of cotton acres planted was irrigated, on average, 71 percent of production came from irrigated acreage. Figure 5 depicts the irrigated/dryland cotton acreage over the past forty years.

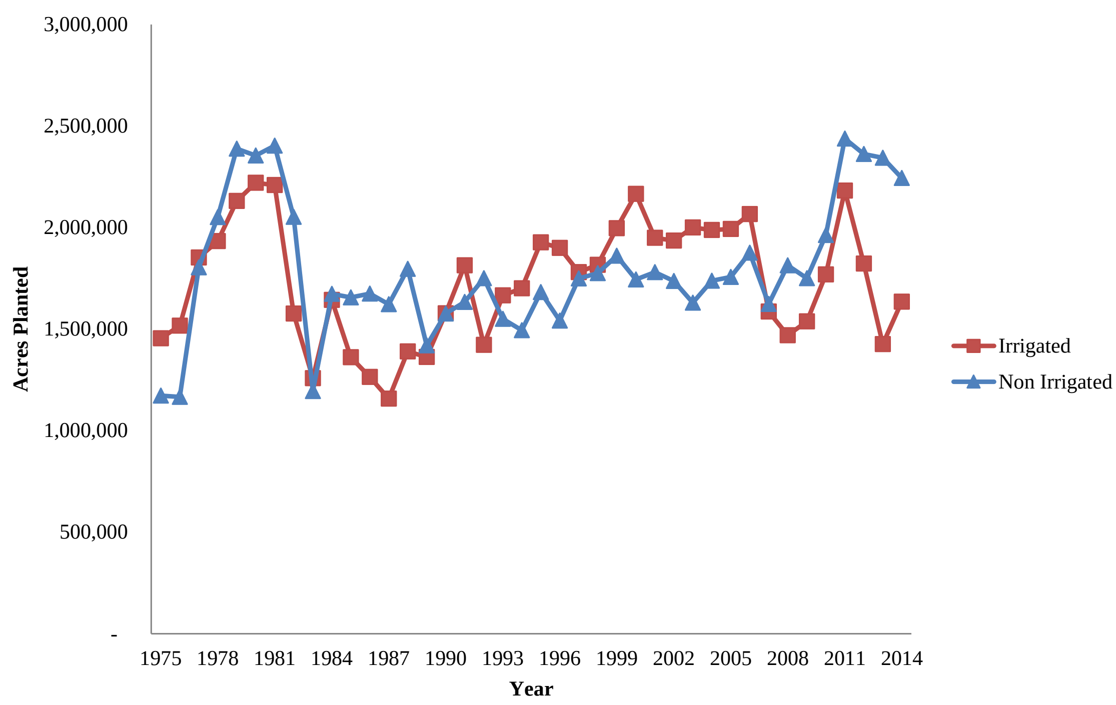

Figure 5. Southern Ogallala Region irrigated/dryland cotton acreage 1975-2014.

Irrigated cotton acreage peaked in the early 1980s reaching a high of 2.2 million acres. Over the next thirty years, irrigated cotton has varied between 1.1 million acres and 2.2 million acres. From the late 1980s to the early 2000s, there was an overall increase in irrigated cotton acreage, however over the past ten years there has been increased volatility with irrigated acres planted. These variations can be linked to changes in both market conditions and farm bill policies. As outlined in subsection 1.3, the introduction of the biofuel era and an increase in livestock to the region has created an incentive for farmers to dedicate irrigated acreage to profit increasing commodities such as feed grains, effectively reducing irrigated acreage available for cotton production. While this trend has been the norm over the past decade, there was a sharp upswing in irrigated cotton acreage in 2011. This increase was a result of cotton production problems in other parts of the world creating a shortage of cotton, driving its price in 2010 to the highest it has been in modern times. These prices influenced agricultural producers to dedicate more land to cotton production. After harvest, the market was flooded with the increase in production, driving prices down. As feed grain prices remained relatively high during this period, the decrease in cotton prices led to a decrease in irrigated cotton acreage planted the following year, and an increase in irrigated feed grain acreage.

Dryland cotton reached a high of 2.4 million acres in 1981 before dropping to an average of 1.6 million acres for the next thirty years. In 2011, dryland acres planted increased to 2.4 million and have remained relatively stable at approximately 2.3 million acres for the past three years.

The high demand for groundwater by agricultural producers coupled with a minimal recharge rate has led to the Ogallala Aquifer’s decreasing water table. This has local leaders and policy makers concerned about the appropriate use of this natural resource. It is important to conduct in-depth analyses of the various agricultural industries in the region as they inform policymakers on the economic impact of a particular commodity or industry within a region and its subsequent ripple effects. The creation and implementation of policies that allow the economic continuity of the agricultural industry in the region while managing the steady decline in the saturated thickness of the Ogallala Aquifer is a daunting task and all available information is needed to make an informed decision for the most effective course of action. For policymakers to accurately assess the viability of future policies, the affected industry and its associated regional economic contribution will need to be considered. The Southern Ogallala Region's cotton industry, in terms of production and processing, is an essential economic staple to the region from both irrigated and dryland acreage. The Southern Ogallala Region centers around agricultural industries and therefore is reliant on the Ogallala Aquifer to sustain their way of life. The decline in the saturated thickness of the aquifer and the desire of agricultural producers to produce high valued, albeit water-intensive crops is causing significant damage to this finite resource. In an attempt to protect the economic viability of the Southern Ogallala Region, this study evaluates the economic impact of the cotton industry and its water needs. The following section outlines the specific objectives of this study.

1.5 Study Objectives

1. Determine the water usage of the cotton industry in the Southern Ogallala Region,
2. Estimate the regional economic value of the cotton industry in the Southern Ogallala Region,
3. Create a basis for the evaluation of the regional economic value of cotton production per unit of water used. This information will aid regional policymakers when considering and implementing future water policies, and
4. Increase the understanding of the value of water as an economic good and its effect on producer's incentives and sustainable agriculture.

CHAPTER II

LITERATURE REVIEW

The literature review is delineated into four sections. The first section provides an overview of studies related to cotton production in the Southern Ogallala Region, the second section includes a brief synopsis of water policies affecting the states in the Southern Ogallala Region, the third section reviews those articles that pertain to water policies and their effect on agriculture, and the fourth section describes the economic impact of agriculture in the region.

2.1 Cotton Production in the Southern Ogallala Region

Almas (2007) sought to analyze the profitability of irrigated cotton, estimate water use efficiency of irrigated cotton, determine the optimum levels of input to maximize output, and estimate the water saving potential of switching from a water-intensive crop to irrigated cotton. This study focused on the Texas Panhandle and to fulfill the objectives, several pertinent pieces of information were required. First, the input variables of total available water, total irrigation, total rainfall, and percent of potential evapotranspiration had to be recorded weekly by participating producers as these variables directly affected the cotton yield. Second, total water availability in comparison to the seasonal water use had to be measured. Third, after harvest, the final crop production data had to be amassed. This information allowed for the creation of a production function demonstrating the relationship between crop yield and amount of water used by the crop.

Data was gathered from 43 different producers in 14 counties of the Texas Panhandle and results indicated that the average amount if irrigation applied was 11.52 acre-inches and the average yield was 1,039 pounds per acre (Almas, 2007). Three separate scenarios were utilized to analyze the management decision of how much water should be applied to the cotton crop to maximize both profit and return on resource. Held constant in each scenario was the price of cotton at $0.50/lb and the price of natural gas (necessary to operate well pumps) at $7.00/mcf. The first scenario utilized as much water as necessary for crop production without concern for the waters origin. The second scenario viewed irrigation as a supplement to natural precipitation and the results indicated that as additional water was supplied to the crop, there came a point when efficiency declined as the response rate from each additional unit of water declined. The third scenario involved the application of water based on the physiological requirement of the crop. The three scenarios held different results as to the acre-inches of water necessary to maximize profits holding cotton and natural gas prices constant. The data is relevant to this study as it demonstrates the different production functions that can be utilized by producers to maximize profits while conserving water and may be of considerable use when implementing future policies.

Reeves (2012) approached irrigation of cotton in the Texas High Plains from an agronomic standpoint instead of a purely economic point of view. An analysis was conducted on the optimum time to cutoff irrigation while maintaining both cotton fiber quality and high yields. This data would cultivate a better understanding of the exact amount of additional water a cotton crop would need while maintaining high fiber quality to maximize profit. By properly timing irrigation termination, producers would be able to maintain a quality crop while ensuring water conservation as no additional units of water would be applied to the crop unnecessarily.

A split plot experimental design in two locations in 2010 and one location in 2011 in the Texas High Plains were used for this study. These plots were subjected to gradual irrigation termination beginning at node after white flower (NAWF 5) 2 weeks, 4 weeks, and a complete termination at 6 weeks. To test the hypothesis that earlier irrigation termination can maintain or improve cotton fiber quality without decreasing overall yield, irrigation and cultivar selection were analyzed separately and then an irrigation and cultivar selection interaction was analyzed within treatment location (Reeves, 2012).

The statistical analysis in 2010 indicated that the particular cultivar selected had a significant effect on lint yield, turnout, strength, length, micronaire, and uniformity. Irrigation had a significant effect on lint yield, seed cotton, length, and micronaire. The interaction between irrigation and cultivar within treatment location varied in statistical significance depending on whether seed cotton (significant), fiber length (significant), or micronaire (not significant) were analyzed. In 2011, the statistical analysis indicated that cultivar selection had a significant effect on length, strength, micronaire, and uniformity while irrigation had a significant effect on seed quality and fiber quality. The interaction between cultivar and irrigation, without location effect as only one location was utilized, indicated that there was a significant effect for this interaction. When considering net income per hectare above the cost of pumping in the years 2010 and 2011, the climate of the Texas High Plains became a significant factor in this study as 2011 was a year of extreme drought for the region (Reeves, 2012).

In 2010, early termination of irrigation at (NAWF 5) 4 weeks proved to be the best treatment when pumping costs were held constant at $6/ha-cm. At this cost, the 2-week and 6-week termination were not statistically significant however when pumping cost increased to $12/ha-cm, the 2-week termination date became statistically different from the 6-week termination date. In 2011, there was no statistical significance between the irrigation termination dates regardless of the cost of pumping as a high amount of water was applied during the growing season due to the severe drought. During this year, the 2-week termination date was preferred due to water conservation. The overall conclusion from the observations of irrigation termination dates is that at lower pumping costs, and an average precipitation year, a 4-week termination date would yield the highest net return. In a drought year, early irrigation termination is desirable mainly to conserve water for a future use in a favorable growing year (Reeves, 2012). Conducting analyses similar to Reeves (2012) allows for more accurate data to be available for producers of agricultural commodities. Producers would have the information necessary to understand the exact water requirements of their crop dependent on the natural precipitation rates of each year and apply only the amount of water necessary to cultivate a high quality crop and maximize net returns.

Nair et al. (2013) analyzed the critical nature of water application in cotton development during each of the three stages of growth: Stage I) planting to appearance of first flower; Stage II) flowering to appearance of first open boll; Stage III) appearance of first open boll to maturity. For cotton producers to adopt strategies that allow for the efficient allocation of irrigation water across each cotton growth stage in an attempt to maximize profit and reduce risk from yearly variation of natural precipitation, a crop growth simulation model, Cotton2K, was used. This model simulated cotton yield under different irrigation schedules and weather patterns and the subsequent data gathered was used in an economic model to determine the optimum strategies for profit maximization and risk minimization. It is assumed that producers embrace different levels of risk based on their individual operations and, to adjust for these preferences, the authors included a sensitivity analysis into their study.

Nair et al. (2013) based their study on the Texas High Plains and adjusted the soil and weather conditions for the Cotton2K software to accurately reflect this region. Soil conditions and agronomic conditions were held constant over 110 cropping seasons from the year 1900 to the year 2009 with the goal of gathering the lint yield of cotton based on four levels of irrigation water; 6, 9, 12, and 15 acre-inches. Daily precipitation and temperature over the period were based on the observations in Plainview, Texas. The profit maximization function was used to calculate the returns for each year under each treatment scenario, holding the price of cotton lint and cost of cultivation constant. The sensitivity analysis was conducted using two methods to determine whether the utility maximizing treatment vary with change in price. The first method held the degree of risk aversion constant at seven varying price levels of cotton lint. The second method held price of cotton lint constant and calculated the expected utility at seven varying coefficients of risk aversion. The results of both methods used in the sensitivity analysis demonstrated that progressive allocation of irrigation water is insensitive to changes in the price of cotton lint and is also insensitive to changes in the degree of risk aversion, resulting in an unchanged expected utility across the four levels of irrigated water availability regardless of price or risk aversion.

The results of the profit maximization portion of the study indicate that Stage II of the cotton growth process (first bloom to first open boll) is the most critical stage for water application. This conclusion held for all water application levels up to 12 acre-inches. When 15 acre-inches were available for irrigation, the authors noted that it was optimal to apply 90 percent of the available water during Stage II of growth and the remaining 10 percent during Stage III. An interesting result showed that applying water in equal quantities throughout the entire growing season resulted in the lowest profit margin on average based on each level of irrigation water availability. The conclusion that can be drawn from these results indicates that at lower irrigation water availability, cotton producers should concentrate all water application during Stage II of the growth process. At higher levels of irrigation water availability, cotton producers should concentrate the majority of water application during Stage II, use the remaining water availability during Stage III, and then Stage I to maximize net returns. The information gathered from using Cotton2K and the subsequent analysis will be highly useful for cotton producers to continue maximizing profits while future water policies cap irrigation water available (Nair et al., 2013).

2.2 Water Policy and the Ogallala Aquifer

Depletion of groundwater resources in the Ogallala Aquifer is a serious concern for those economies that are based on irrigated agriculture. Along with economic growth, increases in population have placed an unusually high amount of strain on already diminishing groundwater resources (Quintana-Ashwell & Peterson, 2015). Groundwater scarcity has led federal, state, and local agencies to implement water conservation policies in an attempt to limit water consumption. However, policymakers will need to consider taking further action as the public and agricultural sectors have an increasing demand for an ever-decreasing supply of water. In order to create effective policies, it is essential for policymakers to have accurate and reliable information about the economic values of groundwater in the Ogallala Region. Water law and policy vary by state; a brief summary of Colorado, Kansas, New Mexico, and Oklahoma law will be covered. As most of this study centers on the High Plains of Texas, an in-depth review of Texas water law will be provided.

Colorado producers must obtain a permit to use groundwater. These permits are considered property rights and can be bought or sold separately from the land where the well is located. No permit will be issued by the Colorado Ground Water Commission unless it has been proven that the well will not deplete the Ogallala Aquifer within a three-mile radius by 40 percent in 100 years. In addition, no new large capacity wells can be drilled within a half mile radius from any other large capacity well drawing upon the same water source (MIT, 2012).

In Kansas, anyone with a permit or a vested right can pump groundwater for nondomestic purposes. Vested right refers to wells that have been in operation since June 28, 1945. There are five Groundwater Management Districts that monitor groundwater use in Kansas and can propose regulations that do not interfere with state laws. These Groundwater Management Districts follow one of two doctrines: safe yield and allowable depletion. Safe yield requires that total groundwater depletion in the district must be a certain percentage of the aquifer recharge in that district. Allowable depletion requires that groundwater use must not deplete the aquifer in the district by more than a specified amount in a specified time (McGuire et al., 2000).

New Mexico water rights are based on the prior appropriation doctrine and any new permits must be granted by the state engineer as long as four criteria are met: "(i) no objections are filed, (ii) unappropriated water exists in the basin, (iii) no infringement on the water rights of prior appropriation occurs, and (iv) it is not detrimental to the public welfare or the water conservation goals of the state" (McGuire et al., 2000). In addition, if water levels decrease by 2.5 feet in one year in a nine to 25-mile radius around the proposed well site, the well will not receive a permit. Water permits rights are sold independently of the land they are located on and, if approval is gained from the state engineer, can be sold out of state (McGuire et al., 2000).

Oklahoma Water Resources Board grants licenses for the use of groundwater. The amount of groundwater that can be withdrawn varies across the state and corresponds with the unique calculation of maximum withdrawal for each region. These calculations are determined by using data from the previous years' water use to set maximum limits for the following year. The goal of this program is to ensure water security for at least twenty years (McGuire et al., 2000).

Currently, two opposing sets of laws and regulations standardize groundwater management in Texas and effect agricultural producers in the Southern Ogallala Region. The first is the "rule of capture" and the second are Groundwater Conservation Districts. The "rule of capture" was implemented in 1904 by the Supreme Court after hearing the case of Houston & T.C. Railway Co. v. East, 98 Tex. 146, 81 S.W. 279. The rule states:

> 'That the person who owns the surface may dig there in, and apply all that is there found to his own purposes, at his free will and pleasure; and that it, in the exercise of such right, he intercepts or drains off the water collected from underground springs in his neighbor's well, this inconvenience to his neighbor fall within the description of damnum absque injuria, which cannot become the ground of an action' (Falk, 2009).

This rule has been upheld for over 100 years despite numerous contestations, and provides a standard for resolving disputes between adjoining landowners. This "rule of capture" has led to many debates concerning future water policy and is the subject of abundant research. On one side, it is thought that by owning the rights to the water below their land, producers can pump water with impunity, regardless of their neighbors' water needs. In addition, the rule of capture has been thought to lead to a wasteful use of water as more can be pumped than may necessarily be needed and causes an unfair dispersal of water allocations among producers as well as promoting environmental damage (Schafersman, 2011). The opposing thought process is that this rule could not possibly be causing the level of damage naysayers are suggesting as it assists in the determination of investments by property owners and water suppliers, and utilized by those acquiring property and planning for water supplies in the future. In addition, stipulations have been added to the rule of capture that producers cannot maliciously pump water in an attempt to injure their neighbor or in a way that produces wanton waste of the valuable resource (Caroom & Maxwell, 2004).

Groundwater Conservation Districts (GCD) were given the power to manage and protect groundwater within their jurisdiction by the Texas Water Code. GCDs are able to exercise their power in one of two ways: rulemaking or permitting. Rulemaking embodies those actions that provide a means of conserving, preserving, or protecting groundwater to prevent both waste and deterioration of water quality. Permitting allows the district to impose limits on the spacing and production of new wells, with the exception of those wells that were previously in use and have been "grandfathered" in. For agricultural producers to create an additional well on their land, they must first receive a permit from their local GCD to proceed (Caroom & Maxwell, 2004). In addition, GCDs are required to design and execute individual water management plans that encompass district "specific objectives and performance standards, detailed actions and procedures designed to effect the plan, and estimates of usable groundwater, groundwater use, recharge, and projected water supply and demand" (Caroom &

Maxwell, 2004). To implement these plans, GCDs are required to use the best available data for their district; a potential use for this study.

Texas House Bill 1763, Texas House Bill 1 and Texas House Bill 2 have been designed to negotiate more stringent groundwater policies as well as promote the need for further analysis of water scarcity and its effect on irrigated agriculture. Desired future conditions were one of the requirements of Texas House Bill 1763 in 2005. These conditions were set by groundwater conservation districts who, in regards to the Ogallala Aquifer, set the future condition as "…an amount of groundwater remaining in the aquifer after a period of time, usually 50 years to coincide with state water plans" (Johnson et al. 2011). In addition to Texas House Bill 1763, Texas Senate Bill 1 (1997) and Texas Senate Bill 2 (2002) have been enacted in response to water scarcity. These Bills worked to reorganize the structure of state water management including developing a statewide water use plan to improve groundwater and surface water management at the local, regional, and state levels (Bian et al., 2015).

2.3 Economic Analysis of Water Policy Scenarios

Wheeler (2008) utilized three policy scenarios to objectively evaluate the efficiency of long and short-term water rights and buyout policies. The authors focused on nine counties in the Southern High Plains of Texas who had a relatively high water use accounting for almost 1.3 million acres of irrigated cropland (cotton, grain sorghum, and wheat). The three scenarios analyzed were: a status quo scenario in which there was no change to current water policy, a long-term water rights buyout program in which cropland is permanently converted to dryland production, and a short-term water rights buyout program in which the cropland is converted to dryland production but allowed to resume irrigated production after fifteen years. The results indicate that the long-term water rights buyout has a higher cost to the economy of the counties under consideration than the short-term water rights buyout. However, the saturated thickness of the Ogallala Aquifer in the region is higher under the long-term buyout than the short-term. In addition, it is noted that the high cost to the economy from the long-term buyout could be offset in such areas that allow other crop alternatives due to soil type and climate.

Johnson et al. (2011) collaborated with Groundwater Conservation Districts (GCD) to analyze two previously conducted studies to demonstrate the rapid progression of water policy research. Under Senate Bill 1, Senate Bill 2, and Texas House Bill 1763, GCDs have been granted more authority to manage groundwater through restrictive rules. Research of water policy originally involved working only toward improving policy models. This increasing level of authority has facilitated opportunities for researchers to work closely with GCDs analyzing economic impacts of specific water policies that are currently under consideration. By providing economic evaluations of policies before they are implemented, policymakers are able to make more informed decisions based on the impacts on agricultural producers and regional economies.

The first study analyzed by Johnson et al. (2011) held "the objective of conducting an economic analysis of how the 50/50 management standard would impact agricultural producers and the overall economy within the region." The 50/50 management standard refers to a management goal implemented by The Panhandle Groundwater Conservation District (PGCD) to allow them to meet a desired future condition of 50 percent of the current water supplies be available in 50 years. The PGCD requested this policy be analyzed from three standpoints: at the county level for two counties within the district, at the study region level for two areas within the counties, and at the farm level for four farms within the counties (Johnson et al., 2011).

The county level analysis for the two county scenario were to be included in the regional analysis if changes were noted, to determine how the 50/50 management standard would affect the regional economy of the PGCD area, encompassing eight counties. The results of this analysis indicated that the 50/50 management standard did not affect the regional economy (Johnson et al., 2011).

Included in the second part of the overall analysis were two study areas of 20,480-acre blocks. These areas were representative of specific areas within the county that were characterized by similar hydrologic and farming practices. It was determined that there was no significant impact to either the study area of the regional economy as a result of the implementation of the 50/50 management standard (Johnson et al., 2011).

Lastly, four representative farms were analyzed to determine any changes that could occur to a standard farming operation in the region—specifically in the farm's ability to generate net cash income. The conclusion drawn indicated that farms were not significantly affected by the 50/50 management standard. However, on those farms with extreme drawdown in saturated thickness, the 50/50 standard affected the present value of net returns by a decrease of $350 over the 50-year time span (Johnson et al., 2011).

The overall results of the first study analyzed by Johnson et al. (2011) indicated that the 50/50 management standard would not significantly affect agriculture at the county, hydrologic area, or representative farm level. Although, in areas experiencing high decline in saturated thickness, the 50/50 management standard could cause a significant impact and should be closely monitored.

The second study conducted by Johnson et al. (2011) was in collaboration with the North Plains Groundwater Conservation District (NPGCD). Their objective was to evaluate the short and long-term economic implications of alternate water conservation strategies being considered. This study evaluated two alternative water conservation strategies and compared them with a status quo baseline scenario. The alternative strategies to be evaluated were desired future condition (DFC) and productivity advancement.

The DFC alternative strategy included two separate future conditions to represent the considerable difference in both water use and aquifer condition between the western and eastern counties in the district. The DFC for the four western counties stipulated that at least 40 percent of the current aquifer storage must remain in 60 years. In contrast, the DFC for the four eastern counties stipulated that at least 50 percent of the current aquifer storage must remain in 60 years (Johnson et al., 2011).

The productivity advancement alternative strategy involved district use of policies, goals and collaboration with agricultural producers and research partners, to develop conservation methods to increase productivity. The objective was to have agricultural producers yield 200 bushels of corn per irrigated acre from 12 acre-inches of groundwater applied. No change in cost structure was to be included as the cost of inputs was unknown (Johnson et al., 2011).

The baseline scenario was run for both the western and eastern counties and assumed no change to current water policies over the 60-year period. The economic optimization models used for this scenario expected a decrease in saturated thickness from 160 feet to 55 feet in the western counties and 201 feet to 166 feet in the eastern counties. The percentage of irrigated acres was expected to drop from 73.7 percent to 31.2 percent in the western counties and 34.7 percent to 34.4 percent in the eastern counties. In addition, the net income per acre was expected to decrease from $271.62 to $83.90 in the western counties but increase from $134.22 to $146.01 in the eastern counties. Over the 60-year period, the total economic output from the western counties was estimated at $33.2 billion while the estimate for the eastern counties over the same period was $16.4 billion. The saturated thickness in two of the western counties was projected to decrease to less than 40 percent of the original water storage by year 50 and by year 60, all four of the western counties had less than 40 percent of the saturated thickness remaining. The eastern counties had at least 65.2 percent of the saturated thickness remaining in year 60 (Johnson et al., 2011).

The results of this study indicated that the DFC scenario had a major impact on the western counties but no impact on the eastern counties as the saturated thickness in that area of the aquifer remained above the set desired future condition. The western counties were projected to realize ten additional feet of saturated thickness in year 60 with a decrease of 3.2 percent in irrigated acreage. Furthermore, producer income was estimated at $271.62 per acre in year 1 and expected to fall from $83.90 per acre (baseline scenario) to $62.95 per acre in year 60 based on the DFC set for the western counties. Economic activity was projected to drop by a total of $1.8 billion as a result of the DFC implementation (Johnson et al., 2011).

The productivity advancement alternate strategy assumed that 200 bushels of corn would be produced from 12 acre-inches of water applied with no additional cost changes. The scenario also presumed that a maximum of 2 percent of acreage could change from one crop to another, per year. When compared to the baseline, saturated thickness in the western counties improved by 16.39 percent over the 60-year period while the eastern counties were projected to experience a 3.5 percent increase in saturated thickness. However, two western counties were expected to fall below 40 percent remaining saturated thickness by year 60. This decrease in saturated thickness is thought to be offset by the 73.19 percent improvement of irrigated acres and increase of 59.07 percent of producer income in the western counties and a 2 percent increase in economic activity over the 60-year time span (Johnson et al., 2011).

2.4 Economic Impact of Agriculture in the Southern Ogallala Region

Terrell (1998) sought to evaluate the economic impact of agricultural production in the Texas High Plains due to a decrease in groundwater available for irrigation. Estimates of future cropping patterns and their value were used to determine the direct, indirect, induced, and total economic impact in the region if depletion of the Ogallala Aquifer continues at its current rate. Other crop allocation models were built for nineteen counties within the Texas High Plains region. The models determined the optimal solution for producers on an individual county basis depending on the water availability in that area as well as the profitability of each crop choice. Using these models, two scenarios were analyzed: one that constrained the percentage of cotton acres that could be grown within a particular county, and one that had no such constraints. These scenarios were used to create an aggregate production function that was compared to the baseline value from Year 1. The resulting values from the aggregate production function comparisons were used to calculate the economic impact in the region. Twelve impact analyses were computed, six per cotton scenario, and the results demonstrated economic trends in terms of output, employment, value added and total impacts. To estimate the regional economic impacts, IMpact analysis for PLANning (IMPLAN), a socio-economic model was used (MIG, 2015).

Results of these analyses confirm the initial conclusion drawn that as the aquifer declines, farmers will be forced to reevaluate their original cropping patterns and shift towards dryland agriculture as water tables decline. Overall, the optimal solution was for producers to cultivate crops that not only utilize less water during the growing season but also generate high net returns relative to the amount water applied to the crop. In regards to the cotton scenarios analyzed, when cotton acres were not constrained, irrigated and dryland cotton were continually the best choice for producers as the net returns of this crop surpassed the other crops included in the study (corn, sorghum, and wheat). However, when cotton acreage was constrained, and dryland cotton was not an option in response to water limitations, dryland wheat acres began to increase (Terrell, 1998).

"Even producing at an optimal solution dominated by cotton production, the region cannot continue its current level of growth and prosperity given a declining irrigation groundwater source" (Terrell, 1998). While the conclusions drawn from this research indicate that cotton would be a viable choice for producers to switch to, it remains that complete groundwater depletion would seriously affect the agricultural industry in this region and ripple through to other segments of the economy as employment and household consumption are affected.

Guerrero et al. (2010) conducted a similar analysis to Terrell (1998) in which the socioeconomic value of irrigated agricultural production in the Texas High Plains was estimated using input-output analysis. Input-output analysis with the IMPLAN model was conducted to determine impacts on final demand, gross output and how the regional economy would react to changes in said demand. The study analyzed two scenarios: the first scenario assumed that producers exhibited unregulated, profit maximization behavior while the second scenario assumed all irrigated agriculture production would be converted to dryland production. Gross receipts per acre of four crops (corn, cotton, sorghum, and wheat) were estimated for both irrigated and dryland and the differences between the two scenarios were applied to the irrigated acreage that was reported in 2008 for each county in the region. The differences in gross receipts were utilized by IMPLAN to estimate their effect on the region's economy.

The author's results showed that a conversion to all dryland production would result in a $1.2 billion smaller contribution to the regional economy. In addition, the value added to the regional economy would decrease by $474 million and employment would fall by 12,113 jobs. Conclusions drawn rely on the assumption that producers will convert all irrigated acreage to dryland. However, Guerrero et al. (2010) indicated that further research is necessary to understand how producers will actually respond to reduced water and the resulting impacts in the regional economy.

Very little literature is focused on the forward-linked sectors of agricultural production. Guerrero et al. (2012) identified the forward links as the added value businesses that are dependent on regional agricultural production, including grain elevators, feedlots, and dairies. Forward-linked models were created to estimate the impact of processing and warehousing of crops on the regional economy. The forward linked estimates, in combination with the backward linked estimates, gave an overall evaluation of the socioeconomic impact of agricultural production. These estimates were used to evaluate three scenarios: desired future conditions, productivity advancement, and a combination of the desired future with productivity advancement.

The Desired Future Conditions scenario was modeled to constrain water use to 40 percent saturated thickness in the western counties of the North Plains Groundwater Conservation District and 50 percent in the eastern counties. Under this scenario, saturated thickness of the aquifer was expected to increase while irrigated acreage was expected to drop. The western counties were expected to lose $1.8 million through backward linked economic activity. The second scenario, productivity advancement, involved the development of a conservation method with increased productivity by assuming 200 bushels of corn could be produced on 12 acre-inches of irrigated water pumped, holding cost constant. The results of this scenario indicate an increase in saturated thickness with an associated increase in both producer income and backward-linked economic activity. The third and final scenario had minimal differences in results from the productivity advancement scenario.

Water conservation efforts are apparent throughout the Southern Ogallala Region with many economists focused on the economic impacts of groundwater policy implementation. Understanding how certain water conservation policies and standards will effect producers and the regional economy will provide a basic framework that can be built upon as more research into the decline of the Ogallala Aquifer is conducted. In addition, agronomists' work on creating a more water efficient cotton crop will assist in the continuance of cotton culture in the region under water conservation strategies.

CHAPTER III

MATERIALS AND METHODS

The fulfillment of the objectives of this study required analysis of the entirety of the cotton industry in the Southern Ogallala Region. This analysis included determining the value of the cotton industry from three standpoints: production, processing, and the combination of production and processing. The following subsections will clearly define the methodology used to generate the results of this study.

3.1 Study Area and Data Sources Used

The study encompasses the Southern Ogallala Region, which includes portions of five states: Colorado, Kansas, New Mexico, Oklahoma, and Texas. However, the cotton industry is concentrated in the Texas High Plains as almost all of the cotton acreage planted and cotton processing in the region occurs in this area. Texas A&M AgriLife Extension Crop and Livestock Budgets projected for 2015 were utilized for most of the data calculations. The Extension Budgets separate the state of Texas into Districts, with Districts 1 and 2 overlapping the Southern Ogallala Region (Figure 6).

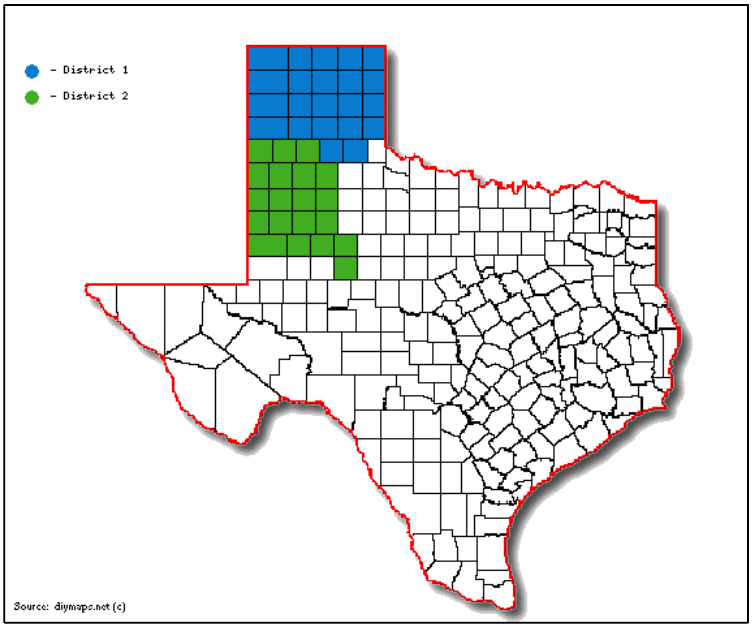

Figure 6. Texas A&M AgriLife Extension Crop and Livestock Budget Map of District 1 and District 2.

National Agricultural Statistics Service (NASS) Quick Stats (2015) was an important resource for gathering statistical data for the agricultural industry of each state. The primary source for data analysis was annual survey data, however if this option was not available, the most recent census data was incorporated into the study (NASS, 2012).

3.2 Acres Planted and Production of Agricultural Commodities

For an accurate assessment of the cotton industry's impact on the regional economy and its estimated water usage, the major agricultural commodities in the area had to be accounted for as they directly influence the amount of water drawn from the aquifer. Data was gathered for alfalfa, corn silage, corn grain, cotton, sorghum, sorghum silage, wheat, and livestock.

The specific crop data collected were acres planted and production through the year 2014, delineated into irrigated and dryland acreage and their respective totals. If any crop had missing data between the years 2010 to 2014, a percent change from the year/years before was applied. If total acres planted or production were given, but not broken into irrigated or dryland acreage, a historical irrigated/dryland breakout percentage was applied to the total to create usable estimates. Once each state and its respective counties had been accounted for, the overall total for each commodity was calculated.

Livestock inventories were collected for beef, dairy, and swine in the study region including eight categories: beef cows, fed beef, summer stockers, winter stockers, dairy cattle, swine breeding, swine nursery, and swine finishing.

3.3 Water Use

There were several pieces of information that had to be collected before water use estimates could be calculated. The average crop yield and the water applied to each commodity in acre-feet per acre were obtained from the Texas A&M AgriLife Extension Service Crop Budgets projected for 2015. In addition, the total irrigated production of each crop, as reported by NASS (2015) was collected.

This data was used to calculate the yield that is generated with each unit (acre-foot) of water applied. The crop yield generated per acre-foot of water applied was estimated by taking the yield per acre of the respective crop and dividing it by the subsequent water applied in acre-feet, Equation 1.

$$\frac{\text{Yield}}{\text{acre-foot}} = \frac{\frac{\text{Yield}}{\text{acre}}}{\frac{\text{Acre-Feet applied}}{\text{acre}}} \quad (1)$$

Then, the estimated number of total acre-feet of water needed to generate the total irrigated production of each crop was calculated, Equation 2.

$$(2) \qquad \text{Total estimated water applied} = \frac{\text{Total Irrigated Production}}{\frac{\text{Yield}}{\text{acre-foot}}}$$

It was important to estimate water use based on the total irrigated production, not from the amount of water that was estimated to be applied to each acre according to the crop budget for two reasons. The crop budget provides a foundation for producers to build on and is not an exact representation of individual producer's needs. For example, one producer may apply less than the estimated water use on his irrigated crops while another producer may apply more than the estimated water use. It cannot be assumed that each producer will use the exact specified amount as detailed by the budget. Furthermore, not every irrigated acre is the same. Yield per acre may be higher or lower than the estimations from the crop budget and, in some instances, a producer may lose a crop altogether. It is these variables that must be taken into account and necessitates the need for a calculation of water use based on total irrigated production to determine the overall amount of water used for each crop.

Finally, the direct water use estimate for livestock was calculated by taking the gallons of water used per head per day and converting this into acre-feet per head per year. This number was then multiplied by the reported inventory (NASS, 2015) for the respective livestock species (Texas Senate Bill 2). The water use of crops and livestock were combined to calculate the total water use by agricultural commodities in the region in 2014. Using this total, the percentage of water used by each agricultural commodity could be evaluated.

3.4 Cotton Lint and Cottonseed Prices

Cotton lint and cottonseed pricing data was collected by year for each state as reported by NASS. Cotton lint was reported in dollars per pound while cottonseed was reported in dollars per ton. As prices fluctuate in individual states for both cotton lint and cottonseed per year, it was necessary to calculate an average price to be used for estimating 2014 values[5]. A three-year average price per state was calculated, using the pricing data for the years 2012, 2013, and 2014.

Calculating the three-year average price allowed for a more accurate analysis as any extreme fluctuations between the years (due to market volatility, climactic conditions, etc.) would be summarized into one amount that would represent the overall trend during this time period.

3.5 Cotton Value from Production Sales

Cotton value from production sales was separated into four categories for each state: Irrigated Cotton Lint Value, Irrigated Cottonseed Value, Dryland Cotton Lint Value, and Dryland Cottonseed Value. Individual state cotton lint values were calculated by first converting the state production, reported in bales, into pounds using 480 pounds per bale produced (NASS, 2015). The production in pounds was then multiplied by the respective states' three-year average price. This method was used for both irrigated and dryland production.

Cottonseed required an additional calculation to determine its valuation. The production (either irrigated or dryland) in bales, once converted to pounds, had to be

[5] Colorado had no planted acreage or production reported for the study period.

multiplied by 1.44 as that is the number of pounds of seed produced per pound of lint (Texas A&M AgriLife Extension Service, 2014). Cottonseed prices are reported in tons, necessitating a conversion of production from pounds to tons to estimate the correct value. The production of cottonseed in pounds was then multiplied by the cottonseed average price for each state to estimate its value.

3.6 Input-Output Model and IMPLAN Analysis

IMpact analysis for PLANning is a socioeconomic input-output model, which utilizes data from the U.S. Department of Commerce, the U.S. Bureau of Labor Statistics, as well as from other federal and state government agencies. These datasets provide detailed data for each county of the United States, allowing analyses to be conducted at the county level, contiguous county level, individual state level, or for a group of states (IMPLAN, 2013). The IMPLAN model was an important tool used in this study and allowed for the estimation of the regional economic impacts of the cotton industry to the Southern Ogallala Region.

Socioeconomic input-output models are conceptually a “spreadsheet of the economy”, providing details on the sales and purchases of goods and services between all sectors of the economy during a given period. Visualizing the model in this way, provides a more comprehensive picture of how a change or “shock” in one sector of the economy will ripple out and affect the rest of the economy. IMPLAN refers to these “shocks” as multipliers and their effects are broken out into three categories: direct, indirect, and induced effects. Multipliers are unique for each sector of the economy and determine the level of interdependence between the industry or sector of choice and the rest of the economy (University of Wisconsin).

These multipliers are used in determining the estimates of three measures of economic activity: industry output, value added, and employment. The following list describes the key terms in the IMPLAN output used to describe the regional economic impact of the cotton industry:

- Direct effects – The sales, income, and employment generated by the farming operations that produce cotton.
- Indirect effects – The purchase of inputs including; seed, chemicals, energy, and machinery that produce cotton.
- Induced effects – Occur when the employees of cotton production and the input suppliers use their income to buy goods and services from businesses.
- Industry output – The total economic activity that occurs within a region as a result of the cotton industry.
- Value added – The income or wealth portion of the cotton industry. This includes employee compensation, proprietary income, property income, and indirect business taxes.
- Employment – The number of jobs created and supported by the cotton industry.

3.7 Determination of Backward Linked Multipliers

"Backward linkage refers to the interconnection of an industry relative to other industries from which it purchases its inputs to produce its output" (Olson & Lindall, 2015). For the cotton industry, the backward linked industries are those that provide goods and services that enable the production of the cotton crop, including: labor cost, purchasing and depreciation of equipment, purchasing of fertilizer and seed, and the ginning process. To assess the impact of these backward linked industries on the cotton industry, analysis-by-parts, an IMPLAN function, was used. Analysis-by-parts allowed for the manual input of goods and services the target industry purchases in order to satisfy a certain production level (IMPLAN, 2013). In this way, the results will be specific to the cotton industry's regional economic impact from both irrigated and dryland cotton inputs. To complete this analysis, a crop budget for irrigated cotton and dryland cotton was applied to the IMPLAN model and the resulting data used to generate the backward linked multipliers. These multipliers reflect the impact per million dollars in the cotton industry for output, value added, and employment in relation to direct, indirect, and induced effects.

3.8 Determination of Forward Linked Industries

Forward linked industries refer to those industries interconnected with the cotton industry and to whom they sell their outputs. In this study, six industries were identified as forward linkages for the cotton industry: cattle ranching and farming, dairy cattle and milk production, soybean and other oilseed processing, fiber, yarn, and thread mills, all other textile mills, and wholesale.

Cattle ranching and farming, dairy cattle and milk production, and soybean and other oilseed processing forward linked multipliers were calculated first and it was assumed that all cottonseed produced would be used for these three sectors in the region. The amount of cottonseed in the diary rations, reported in tons as fed, was multiplied by the cottonseed three-year average price to determine the sales of cotton to the dairy sector (Guerrero et al., 2012). Next, IMPLAN provided the use coefficient, or the percent of each dollar that was generated by the cotton industry in that sector, for soybean and other oilseed processing. The use coefficient was multiplied by the sector's output, provided by IMPLAN, to determine the value of the sales of cotton to the soybean and other oilseed processing sector. It was assumed that all other value generated from cottonseed sales were from the cattle ranching and farming sector.

The sales of cotton to the fiber, yarn, and thread mills and all other textile mills sectors was determined by taking the use coefficient and multiplying it by the output (both pulled from IMPLAN), to determine the sales value. All other textile mills did not have a unique use coefficient in IMPLAN, so the use coefficient from the closely related sector of fiber filaments was used instead.

The sales of cotton to the wholesale sector was determined by calculating the value added from cotton warehousing or $14.65/bale multiplied by cotton production (in bales) in 2014 (Harkey, 2015). Once the value of sales of cotton to each forward linked sector was calculated, it was multiplied by the backward linked multipliers pulled directly from IMPLAN for that sector to determine the forward linked impacts of the purchasing sector that could be attributed to cotton production. The total forward linked impacts were calculated first, and then they were proportioned by state.

3.9 The Cotton Industry's Contribution

Several steps were required to calculate the economic contribution of the cotton industry to the Southern Ogallala Regional economy. The first step was to calculate the value of irrigated production, dryland production, and total production. These values were calculated by state then by region and separated into output, value added, and employment by direct, indirect, and induced effects.

To accomplish this task, the respective states' irrigated or dryland production value (calculated by the process described in subsection 3.5) was multiplied by the corresponding backward linked multiplier. For example, the irrigated cotton production value for Texas was multiplied by the backward linked multipliers to obtain the direct, indirect, and induced impact. This method was used for the other three states that recorded cotton production during the study period. This process was then repeated for dryland cotton production. Colorado had no impact since there was no cotton production reported in the state for 2014

Cotton processing calculations were completed for all five states in the study region as they each reported cotton processing during the study period. The IMPLAN output for those forward linked sectors associated with the cotton industry within the region were used in combination with the forward-linked multipliers provided by IMPLAN to determine the value of cotton processing. Once processing values were estimated by state, a total for the region was calculated.

After individual state and total cotton production and processing were calculated, a grand total was estimated to determine the impact production and processing had on the regional economy[6]. Totals were first determined by state and then overall total regional economic impact was calculated.

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[6] Total cotton production (irrigated and dryland production combined) was used for this estimate.

The forward linked industry sectors of the IMPLAN output do not separate processing on the basis of irrigation. This made it necessary for an irrigated and dryland breakout percentage to be applied to the total cotton processing value to estimate the value of irrigated cotton processing. Total irrigated cotton value was divided by the total cotton value to create the percentage of value incurred from irrigation. This percentage was then applied to the total cotton processing values, as described above, to estimate total irrigated processing.

The final water calculation was the determination of value per acre-foot of water applied to the cotton crop from the regional economic impact of production, and then from the combination of production and processing. Value of production per acre-foot of water applied was calculated by taking the grand total of acre-feet of water applied to cotton in the region in 2014 (subsection 3.3) and dividing it by total irrigated production. Value of production and processing per acre-foot was calculated by taking the grand total of acre-feet of water applied to the cotton crop in the region in 2014, and dividing it by the total irrigated production and processing value.

CHAPTER IV

RESULTS

The total value of cotton production (lint and cottonseed) in 2014 surpassed $1.3 billion; irrigated cotton cropland yielded 71 percent of this total. In 2014, cotton ranked third in water usage for production in the region using just 12.6 percent of the total water consumption from agricultural commodities for the year.

4.1 Regional Acres Planted

The study region totaled 19.8 million acres of cropland broken out into 12.6 million acres of dryland and 7.2 million acres of irrigated. Of this total, cotton accounted for 3.9 million acres or 20 percent of the study region and 36 percent of the total cotton acreage planted nationally in 2014. Irrigated cotton acreage has fluctuated greatly over the past forty years realizing highs of 2.2 million planted acres to lows of 1.1 million acres. The past ten years have been especially volatile for irrigated cotton acreage and in 2014 the total irrigated cotton acres planted in the region reached 1.6 million acres. Over the same period, dryland cotton acres planted have fluctuated from a high of 2.4 million acres to a low of 1.2 million acres. From 2012 to 2014 dryland acreage has remained stable at 2.3 million acres and represents 58 percent of total cotton acreage in the region

The Southern Ogallala Region alone produces 21 percent of the total cotton produced annually in the United States (NASS, 2015).

4.2 Estimated Water Use for Cotton Production

Estimated water use for cotton production was calculated based off values for yield-per-acre and direct irrigation applied (acre-inch per acre) provided by Texas A&M AgriLife Extension Crop and Livestock Budgets (2014). Both District 1 and District 2 were averaged for use in IMPLAN, while District 2 was used for water use estimates as most of the irrigated cotton production occurred in this district of Texas. Irrigated cotton lint production totaled more than 1.1 billion pounds while cottonseed was estimated to be over 800,000 tons (Table 1). According to the cotton crop budget, 1,250 pounds of cotton are produced per irrigated acre and one-acre foot of water is applied to produce that yield. Using the calculations outlined in section 3.3, production of 1.1 billion pounds of cotton lint required an estimated 903,708 acre-feet of water.

Table 1. Estimated water use for irrigated cotton production in the study area, 2014.

	Cotton (pounds)	Cottonseed (tons)
Production	1,129,635,411	813,337
Yield/Acre	1,250	0.9
Acre-feet of Water Applied Per Acre	1	1
Total Estimated Water Applied (ac-ft.)	903,708	

The Texas High Plains consumed the vast majority of water for irrigated cotton at an estimated 884,390 acre-feet of water used in the region or 97.9 percent (Table 2). The remaining states had a combined water use estimate of just over 19,000 or 2.1 percent of the total. New Mexico's water use estimate was 13,203 acre-feet or 1.5 percent, while

Kansas and Oklahoma combined used 6,115 acre-feet of water or 0.6 percent. No cotton production was reported in Colorado.

Table 2. Estimated water use (acre-feet) for irrigated cotton production in the Southern Ogallala Region by state, 2014.

Region	Cotton (acre-feet)	Water Use (%)
Colorado	-	-%
Kansas	3,571	0.4%
New Mexico	13,203	1.5%
Oklahoma	2,544	0.2%
Texas	884,390	97.9%
Total	903,708	100.0%

4.3 Allocation of Water to Agricultural Commodities

An accurate assessment of water use estimates for agricultural commodities in the Southern Ogallala Region necessitated a complete water use analysis for each commodity. Livestock and crop water use estimates were first calculated by individual commodity before being summed to estimate the total water use by the agricultural sector. In 2014, agricultural commodities in the Southern Ogallala Region used a total of 7,154,393 acre-feet of water. Cotton accounted for 903,708 acre-feet or 12.6 percent of water use in the study region (Figure 3), ranking third in water usage behind corn (56.5 percent) and wheat (12.9 percent). Overall, crop production used an estimated 7,031,587 acre-feet of water or 98.3 percent of regional water use in 2014. Livestock's direct water use estimate totaled 122,806 acre-feet or 1.7 percent of the water use in the region. Groundwater use varies on a yearly basis depending on climactic conditions, acres planted, and livestock numbers. In 2014, the annual water use by the agricultural sector was the sixth highest compared to estimates over the past decade.

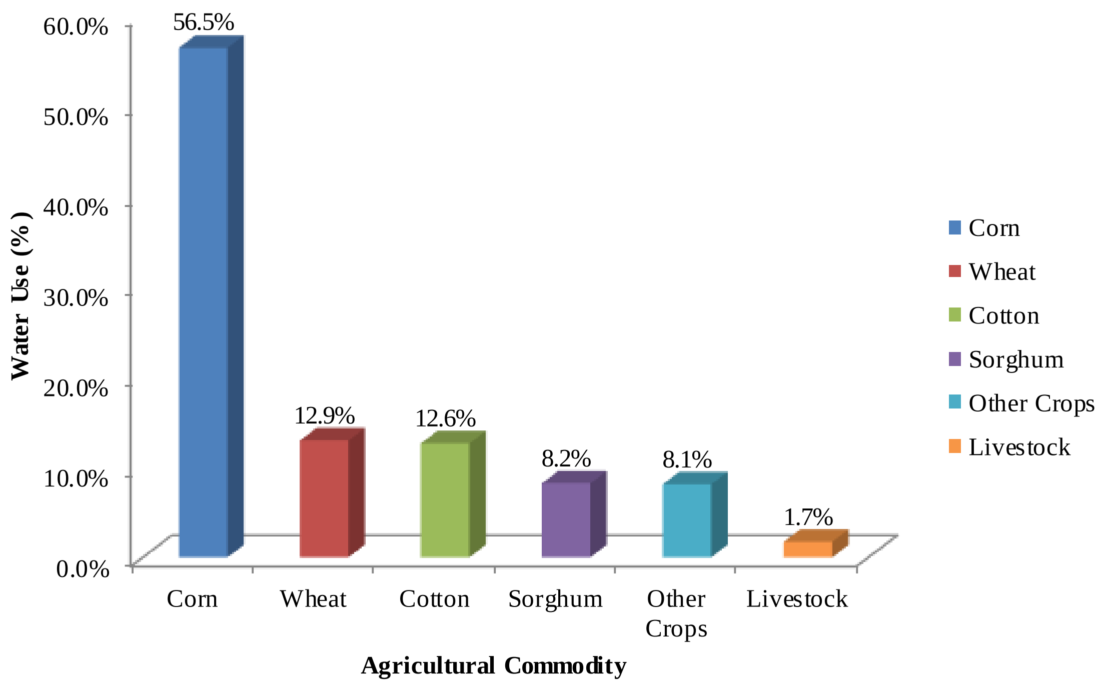

Figure 7. Estimated percentage of water use by the cotton industry in comparison to other agricultural commodities in the Southern Ogallala Region, 2014.

4.4 Direct Value of Cotton Lint, Cottonseed Sales, and Cotton Processing

Irrigated cotton production was over 1.1 billion pounds of lint and 813,337 tons of cottonseed in 2014 (Table 3). Dryland cotton was included in the cotton production estimation as it contributes to the regional economy without affecting water use estimates. In 2014, dryland cotton production exceeded 460 million pounds of lint and over 300,000 tons of cottonseed.

Table 3. Cotton production by State in the Southern Ogallala Region, 2014.

Region	Irrigated Cotton Lint (pounds)	Irrigated Cottonseed (tons)	Dryland Cotton Lint (pounds)	Dryland Cottonseed (tons)
Colorado	-	-	-	-
Kansas	4,463,450	3,214	200,745	145
New Mexico	16,503,666	11,883	845,947	609
Oklahoma	3,180,296	2,290	-	-
Texas	1,105,488,000	795,951	459,888,000	331,119
Total	1,129,635,412	813,338	460,934,692	331,873

Subsection 3.5 outlines the process utilized for calculating the sales from cotton lint and cottonseed production by state. Sales from cotton production (irrigated and dryland) in the region was valued at over $1.35 billion in 2014 (Table 4). Of this total, $960 million or 71 percent of cotton's direct value was a result of irrigated cotton production from both lint and cottonseed with the remaining $391 million attributed to dryland cotton production. In 2014, irrigated and dryland cotton lint direct value was just over $1 billion dollars while cottonseed direct value was $267 million.

Table 4. Sales from cotton lint and cottonseed production by state in the Southern Ogallala Region, 2014.

	Kansas	New Mexico	Oklahoma	Texas	Total
	Irrigated Cotton Value				
Cotton Lint	$3,058,951	$11,998,990	$2,222,232	$753,279,523	$770,559,696
Cottonseed	$696,298	$3,331,100	$496,126	$185,721,984	$190,245,508
Total	$3,755,249	$15,330,090	$2,718,358	$939,001,507	**$960,805,204**
	Dryland Cotton Value				
Cotton Lint	$137,577	$615,046	$-	$313,367,683	$314,120,306
Cottonseed	$31,316	$170,746	$-	$77,261,184	$77,463,246
Total	$168,893	$785,792	$-	$390,628,867	**$391,583,553**
	Total Cotton Value				
	$3,924,142	$16,115,882	$2,718,358	$1,329,630,374	**$1,352,388,757**

Analysis of the value of cotton production by state reveals that of the five states included in this study, Texas accounts for the majority of cotton production in the study region. The Texas High Plains accounts for $1.32 billion or 98.3 percent of total crop receipts. New Mexico is the second leading state with $16 million in crop receipts or 1.2 percent of the total sales from cotton production. Kansas and Oklahoma combined had over $6 million or 0.5 percent of the total crop receipts.

The direct value of cotton processing was $319 million in 2014 (Table 5). Combined with production, the total direct output exceeded $1.6 billion in 2014. The Texas High Plains was responsible for $186 million or 58 percent of the processing total and 90.6 percent of the total direct output of the cotton industry. Kansas was the second leading state in terms of cotton processing with $77 million or 25 percent of the total. New Mexico (11 percent), Colorado (4 percent) and Oklahoma (2 percent) made up the remaining $56 million from cotton processing. While Colorado reported no cotton production in the region, the state did report direct output from cotton processing.

Table 5. Sales from cotton production and processing sectors in the Southern Ogallala Region, 2014

Region	Cotton Production	Cotton Processing	Total Cotton Industry
Colorado	$-	$13,798,316	$13,798,316
Kansas	$3,924,143	$77,762,641	$81,686,784
New Mexico	$16,115,882	$35,258,262	$51,374,144
Oklahoma	$2,718,358	$6,889,489	$9,607,847
Texas	$1,329,630,374	$186,284,123	$1,515,914,497
Total	$1,352,388,757	$319,992,831	$1,672,381,588

4.5 Production Value of Cotton in the Southern Ogallala Region

The sales from cotton production, as reported in the previous section, were used as an input to IMPLAN to calculate the regional economic value of irrigated and dryland cotton production. The backward linked multipliers (identified in subsection 3.8) were used in conjunction with the calculated cotton values to create Table 6, which presents the direct, indirect, and induced value of cotton production for the region in 2014. The total economic contribution of irrigated cotton production was valued at $1.9 billion creating value added of $733 million and supporting over 16,000 jobs. Comparatively, dryland cotton's total output was valued at $899 million with $285 million in value added and the support of almost 8,000 jobs. Cumulatively, irrigated and dryland cotton production resulted in a $2.8 billion economic contribution related to total output to the region with an additional $1 billion in value added and supported over 24,000 jobs in 2014. A complete breakdown by state of cotton production is included in Appendix A.

Table 6. Economic contribution of the cotton production sectors to the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Irrigated Cotton Production			
Output	$960,805,204	$777,076,190	$200,418,201	$1,938,299,595
Value Added	$274,071,304	$343,260,150	$116,091,210	$733,422,664
Employment	7,309	7,206	1,729	16,244
	Dryland Cotton Production			
Output	$391,583,553	$408,333,539	$99,665,846	$899,582,938
Value Added	$34,510,810	$193,456,372	$57,713,542	$285,680,724
Employment	2,979	4,112	861	7,952
	Total Cotton Production			
Output	$1,352,388,757	$1,185,409,729	$300,084,047	$2,837,882,533
Value Added	$308,582,114	$536,716,522	$173,804,752	$1,019,103,388
Employment	10,288	11,318	2,590	24,196

Direct effects are the sales, income, and employment generated by farming operations that produce cotton. In terms of direct output, irrigated cotton production was valued at 2.5 times the value of dryland cotton, $960 million compared to $391 million, respectively. Direct value added showed a significant difference between irrigated and dryland cotton production. Irrigated cotton's direct value added of $274 million was eight times that of dryland cotton's $34 million regional economic contribution. In addition, direct employment by irrigated cotton was about 2.5 times that of dryland cotton, 7,300 and 3,000 jobs respectively.

Indirect effects are the secondary inputs used in the production of cotton, i.e. seed, fertilizer, and machinery. Indirect output for irrigated cotton production totaled just over $777 million, with dryland production generating $408 million. Indirect value added generated $343 million from irrigated cotton while dryland value added contributed $193 million. Total indirect employment was estimated at over 11,000 jobs; 7,200 from irrigated cotton production and 4,100 from dryland cotton production.

Induced effects occur when employees of cotton operations or suppliers of inputs necessary for cotton production spend their income to buy goods and services in the regional marketplace. Irrigated cotton production induced output generated over $200 million while value added totaled $116 million and employment reached more than 1,700. Dryland cotton production induced output was just under $100 million, with value added of $57 million and support of over 800 jobs.

4.6 Processing Value of Cotton in the Southern Ogallala Region

The economic contribution of cotton processing was calculated using the forward linked multipliers discussed in subsection 3.9 and estimated using the procedure outlined in subsection 3.10. Table 7 is a summary of the IMPLAN output from the cotton processing sectors and Figure 8 is an illustration of the production and processing value from irrigated and dryland acreage. Estimates by state for cotton processing are included in Appendix A.

Table 7. Economic contribution of the cotton processing sectors to the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Irrigated Cotton Processing			
Output	$227,194,890	$94,191,293	$22,235,720	$343,621,903
Value Added	$69,104,498	$33,286,494	$12,685,336	$115,076,328
Employment	834	450	213	1,497
	Dryland Cotton Processing			
Output	$92,797,913	$38,472,500	$9,082,196	$140,352,609
Value Added	$28,225,780	$13,595,892	$5,181,334	$47,003,006
Employment	341	184	87	612
	Total Cotton Processing			
Output	$319,992,803	$132,663,793	$31,317,916	$483,974,512
Value Added	$97,330,278	$46,882,386	$17,866,670	$162,079,334
Employment	1,175	634	300	2,109

Irrigated cotton's total processing output was valued at $343 million, with $115 million in value added and support of almost 1,500 jobs. Dryland cotton processing generated $140 million in total output, $47 million in value added, and supported over 600 jobs.

Direct output for irrigated cotton processing was valued at over $227 million, 2.5 times the dryland cotton processing value of $92 million. Direct value added for irrigated cotton reached almost $70 million while dryland cotton was just under $30 million. Direct employment for irrigated cotton was about 2.5 times that of dryland cotton, supporting around 800 jobs and 350 jobs respectively.

Indirect output for irrigated cotton processing was valued at $94 million compared to $38 million for dryland cotton processing. Indirect value added for irrigated cotton generated just over $33 million while dryland cotton reached nearly $14 million.

Irrigated indirect employment supported 450 jobs compared to dryland cotton's indirect employment of 180 jobs.

Induced effects were lower than the other two categories analyzed using IMPLAN. Induced effects are typically lower as they represent the spending income of the direct employees -for example, the management and laborers of the producer - and indirect employees - for example, the seed company employees. Induced output for irrigated cotton processing was valued at $22 million while dryland cotton processing generated $9 million. Induced value added for irrigated cotton generated over $12 million and supported over 200 jobs. Dryland cotton processing induced value added was estimated at $5 million and supported under 100 jobs.

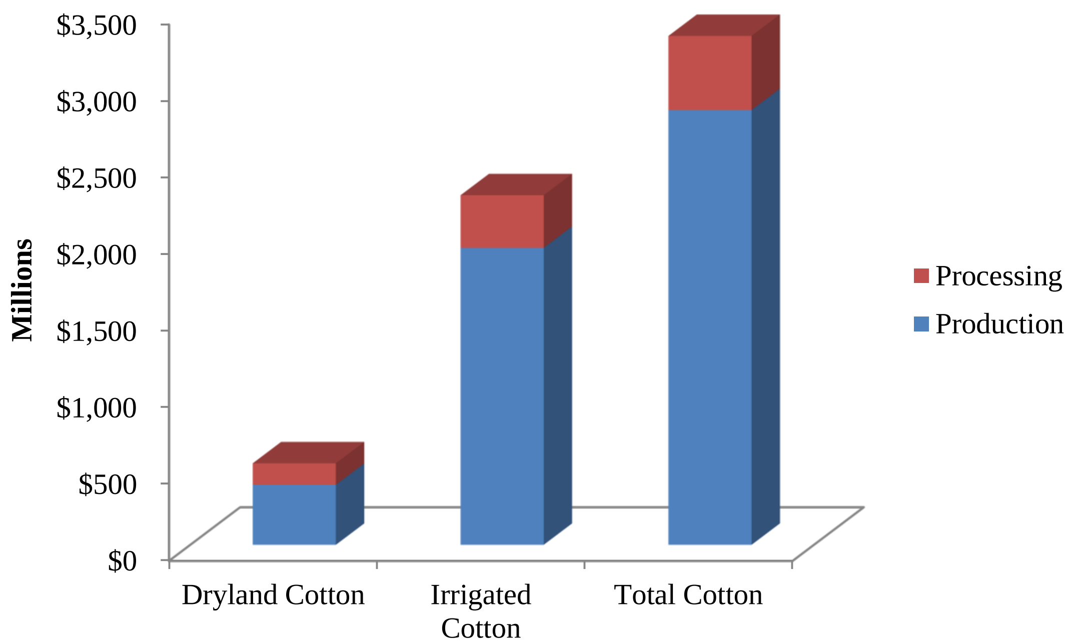

Figure 8. Economic contribution of irrigated and dryland cotton to the Southern Ogallala Region, 2014.

4.7 The Economic Contribution of the Cotton Industry and the Value of Water

The output of the cotton industry, including the production and processing sectors, contributed over $3.3 billion to the economy of the Southern Ogallala Region, Table 8, and value added or wealth generated an additional $1.1 billion. Employment supported by the cotton industry, including direct, indirect and induced effects was estimated at over 26,000 jobs. Cotton production compared to the cotton processing sector considering both irrigated and dryland production, accounted for 85 percent of the total output, 84 percent of value added and 91 percent of employment.

Table 8. Economic contribution of the cotton production and processing sectors to the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$1,352,388,757	$1,185,409,729	$300,084,047	$2,837,882,533
Value Added	$308,582,114	$536,716,522	$173,804,752	$1,019,103,388
Employment	10,288	11,318	2,590	24,196
	Cotton Processing			
Output	$319,992,830	$132,663,808	$31,317,918	$483,974,556
Value Added	$97,330,279	$46,882,386	$17,866,670	$162,079,335
Employment	1,175	634	300	2,109
	Total Cotton industry			
Output	$1,672,381,587	$1,318,073,537	$331,401,965	$3,321,857,089
Value Added	$405,912,393	$583,598,908	$191,671,422	$1,181,182,723
Employment	11,463	11,952	2,890	26,305

In addition to understanding the economic value of the cotton industry from both dryland and irrigated cotton in the Southern Ogallala Region, it was important to calculate the value of the water applied for irrigated cotton production and processing. These calculations create a standard basis that can be used to compare the values of the separate agricultural industries in the region. Policymakers would be able to easily assess the value of water from production and production and processing from each commodity and incorporate these numbers into the formulation of future water policy. The value per acre-foot of water applied should not be used as the only deciding factor, but as a guide to assist producers and policymakers.

Subsection 3.10 defines the estimation process for determining the value of water applied. When considering only irrigated cotton production, the value of water applied was $2,145 per acre-foot. When irrigated processing sector was included in the calculation, the value of water applied increased to $2,525 per acre-foot (Table 9).

Table 9. Regional economic value per acre-foot of water of water applied from production and production and processing, 2014.

	Production	Production and Processing
Regional Economic Value	$1,938,299,595	$2,282,139,536
Ac-ft. applied	903,708	903,708
Value/Ac-ft.	$2,145	$2,525

These estimates assist regional planners with water conservation strategies by evaluating the water use and economic impact given the water use of the different agricultural industries. Calculating the regional economic value per acre-foot applied allows for a better understanding of the economic impact of the cotton industry to the Southern Ogallala Region and used as a basis for comparison between agricultural commodities produced in the region.

CHAPTER V

USING MARGINAL VALUE OF WATER TO FORMULATE WATER POLICIES

At the 1992 International Conference on Water and the Environment, it was stated, “managing water as an economic good is an important way of achieving efficient and equitable use and of encouraging conversation and protection of water resources”. This statement does not imply that the only efficient method to managing water is through the competitive market. Instead, as a unique economic good, there are numerous externalities associated with water, necessitating the combination of nonmarket valuation techniques and traditional economic evaluation to ascertain the value of water.

The following sections will describe the process of assigning value to water. First, it must be determined if water is a public or private good, then the nonmarket valuation techniques and their role in determining the value of water will be analyzed. In addition, any discussion involving water conservation must include the topic of sustainable agriculture. Once these broad topics are addressed, the final sections will discuss the primary objective of agricultural producers and differing ways to value water used for agricultural production in the Southern Ogallala Region.

5.1 Water: Public or Private Good?

While there are many ways to classify goods and services in economic theory, it is beneficial to use the terms public or private when referring to an economic good for the purpose of formulating water policy. A public good is one in which the consumption of the good does not reduce the amount available to others; therefore, there is no associated opportunity cost. In addition, it is simply not possible to exclude nonpayers from consuming this good, making a public good both nonrivalrous and nonexcludable. In contrast, the consumption of a private good reduces the amount available to others and institutional arrangements can be enforced that exclude the use of this good from nonpaying individuals. Examples of water as a public good include lakes, rivers, and flood risk reductions while water as a private good involves agricultural, industrial, or household consumption (Young, 2005).

Herein lays the difficulty with classifying water using a single economic term. Water is the sustaining component of life, to classify it as strictly a private good would infringe upon basic human rights, however to classify it as a strictly public good could lead to mass overuse of this resource as restrictions would not be in place. Natural resource economists have found that a combination of the two categories is the most efficient way to solve this problem: water is a public good until basic survival needs are met and any additional water usage would be considered the consumption of a private good (Green, 2003).

Treating water as economic good and using economic methods to estimate the value of water is a starting point when creating policy. However, there are numerous unique characteristics of water that create additional factors and impacts that can be difficult to qualify. For example, a producer will use the amount of groundwater necessary to satisfy their crops' water need and will incur costs associated with this level of water use. Not included in this cost is the reduction of water available for other production operations, local fisheries, recreational uses, etc. These opportunity costs are not reflected in the market price of pumping or transporting water and therefore not generally considered by producers when determining the amount of groundwater to apply to their crop. Subsequently, policymakers are faced with the task of identifying all externalities, both positive and negative, associated with water use and incorporating them into the decision making process (White, 2015).

5.2 Nonmarket Valuation of Water

The economic value of a resource can be determined by how much a consumer will pay for a good instead of doing without, or the amount of compensation a consumer will accept to do without said good. This economic value assigns a price relative to the market demand and provides a market allowing for the efficient allocation of the resource that aligns with consumer and producer objectives. In economics, efficient allocation of resources is known as Pareto efficiency or "there is no other allocation in which some other individual is better off and no individual is worse off" (Osborne, 1997). As discussed above, water can be qualified as both a public and private good and therefore the assumption that this resource has not always been allocated in an economically efficient manner can be made. Therefore, to determine the value of water and its allocation in an economically efficient manner, nonmarket valuation techniques are a necessary consideration. This section describes several of these techniques and their implications for the Ogallala Aquifer, however a true analysis involving these methods would be the subject of another study.

Nonmarket valuation methods attempt to fulfill objectives outlined by the governing bodies of a resource. The U.S. Water Resources Council in 1983 and the Organization for Economic Cooperation and Development in 1985 outlined the following objectives:

1. Enhancing national economic development,
2. Enhancing regional economic development,
3. Enhancing environmental quality, and
4. Enhancing social well-being

These objectives attempt to enforce a central concept in resource economics; environmental impacts should be balanced against human welfare considerations. To achieve this balance, nonmarket valuations are incorporated into the policy formulation process to create a more comprehensive view of policy effectiveness (Young, 2005).

Objectives 2 and 3 are the driving force behind water policies; especially those concerning the Ogallala Aquifer and the future of rural communities, cities, and the agricultural industries that rely on water for their operations. There are several prevalent methods of nonmarket valuation of agricultural water that can be used to fulfill these objectives, including: observations of water market transactions, econometric estimation of production and cost functions, hedonic property value, contingent valuation, basic residual, change in net returns, value-added, computable general equilibrium, and alternative cost (Young, 2005). While studies have been conducted utilizing these methods, nonmarket valuation is still an underrepresented topic among literature regarding water valuation and regulation.

5.3 Agricultural Producer Incentives: Profit Maximization and Irrigation

It is a general assumption in economics that rational firms will seek to maximize profits. In economics, profit is simply total revenue minus total costs (including opportunity costs). Profit maximization seeks to increase total revenue while decreasing total costs to the point where the difference is at its maximum. As agricultural producers operate in a competitive market, they attempt to maximize profits over the short run, or where the marginal revenue received from producing their product equals the marginal cost of producing said product. The incentives of producers to maximize profits in the Southern Ogallala Region will be examined in this section.

The success of agricultural producers in this region is due in part from the ability to access the Ogallala Aquifer for irrigation needs, allowing them to realize higher crop yields, increased profits, and reduced risk. In addition, the climate of the region supports a wide variety of agricultural products creating the opportunity for diverse operations. As stated previously, irrigation production on average generates three times the value of its dryland counterpart, and feed grains (such as corn) receive higher premiums in the Southern Ogallala Region as a result of the region being grain deficit (consumption outweighs production). While there is significant evidence supporting the role of irrigation and production mix in increasing farm profits, there are additional factors to take into consideration that affect the implementation of these practices and the overall goal of profit maximization. Furthermore, irrigation or the production of certain crops may not be a logistical option on an individual farm basis. This does not mean profit maximization is not possible. Instead, profit maximization will occur given the characteristics of the farm and the individual operational goals. Analyzing the various production scenarios involving dryland/irrigated production and crop mixes is the subject for further study. The remainder of this subsection will provide a general overview of the effect of irrigation and high valued crops on agricultural producer incentives.

Availability of surface water or groundwater is obviously necessary to support an irrigated operation, but access to these resources is not always available. In the Southern Ogallala Region, precipitation rates are unpredictable and vary greatly year-to-year. In those years with low precipitation, there is an increased reliance on the aquifer to satisfy water needs. Depending on the location of individual farms in this region, the underlying aquifer may be utilized to supplement rainfall in order to sustain the operation; however, it is likely that at some point in the future, the water table will decrease to a point where it will be impossible to reach the groundwater stores or become too expensive to pump. Some portions of the region have already realized a major decline in the water table, making irrigation an infeasible option. In these two cases, the first with eventual groundwater depletion and the second, those who have already realized depletion, the profit maximizing decision will not include irrigation and alternative strategies or factors will need to be considered.

Another way for producers to enhance profit is the inclusion of higher valued crops into the production mix. However, this strategy may not always result in increased profit. For example, an increase in revenue may not lead to profit maximization as higher input costs may be incurred to create that additional revenue. Producers must analyze several factors from both the revenue and cost side of the equation to determine the production mix that will generate maximum profit. Factors affecting revenue from commodity sales include market price, quality of commodity sold, and yield. Factors affecting costs include any increases in fertilizer, labor, custom harvesting, and insurance. The complexity of this equation increases as various scenarios are included along with estimates of future market conditions. In addition, higher valued crops may require additional water, which may or may not be available to the producer.

Agricultural producers compete in a market with homogenous products, realizing the need to maximize profits to remain viable. Achieving profit maximization will be unique to the individual agribusiness. For those producers able to use irrigation and/or plant high valued crops, it is likely that, in the short run, they will gravitate towards incorporating these methods into their operations. Without water restrictions, the rational farmer will use as much water as required by the commodity produced with the goal of achieving higher yields and profits. While great strides have been made in the efficiency of irrigation technology, eventually the water table of the aquifer will decrease to a level where it is no longer a viable supplemental resource in this region. This reality makes it necessary to understand the value that irrigation adds to a producer's operation in an attempt to allocate this resource efficiently and effectively.

5.4 Market Valuation of Water in the Southern Ogallala Aquifer Region

Three different market estimates were used to analyze the value of water as it pertains to a particular outcome or use. These three estimates included: calculating the value that irrigated cotton brings to a producer in comparison to dryland cotton, comparing the regional economic impact value per acre-foot between cotton, feed grains, and small grains, and comparing the rural land value.

The first estimate was calculated using the Texas A&M AgriLife Extension Crop and Livestock Budgets projected for 2015 in District 2 for irrigated and dryland cotton[7]. Irrigated cotton was projected to yield 1,250 pounds of lint at $0.70 per pound and 0.90 tons of cottonseed at $250 per ton with total revenue of $1,100.00 per acre. Dryland cotton was projected to yield 350 pounds of lint at $0.70 per pound and 0.25 tons of cottonseed at $250 per ton with total revenue of $380.00 per acre. In addition, irrigated cotton returns above specified costs were projected to be $223.57 per acre whereas dryland cotton returns above specified costs were projected to be -$15.93 per acre. The difference of $239.50 per acre in returns above specified costs (profit) indicates the value one acre-foot of water directly to the agricultural producer. Applying an acre-foot of water increases both cotton yield and returns above specified costs.

The valuation of water can be expanded past the direct impacts to producer profitability to also include the ripple effects of irrigated agricultural production to the regional economy. The second estimate was calculated in subsection 4.7 when determining the value of water per acre-foot from production and from production and

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[7]This budget was chosen as it reflected the study year and one of the regions where cotton is predominantly grown. This estimate could be made using the budget of any district.

processing. This value per acre-foot of water applied can be separated out into direct, indirect, and induced impacts to the regional economy from both irrigated production and irrigated production and processing. Irrigated cotton production's direct impact was $1,062 per acre-foot of water applied, indirect was $862, and induced was $221, for a total of $2,145 per acre-foot. When considering irrigated production and processing, an additional contribution of $380 per acre-foot of water applied is generated for a total of $2,525 per acre-foot. It is important to understand the value of water from direct, indirect, and induced effects as it allows for a better understanding of each of the economic impacts generated from cotton production.

The regional economic value of water from cotton production and processing was compared to feed grains and small grains production to give a general idea of the differences in the economic contribution of alternative cropping industries, Table 10..

Table 10. Comparison of the Regional Economic Value of Water per acre-foot from Cotton, Small Grains, and Feed Grains Production and Processing.

	Cotton		Small Grains[a]		Feed Grains[b]	
	Production	Production and Processing	Production	Production and Processing	Production	Production and Processing
Ac-ft. applied	903,708		1,084,686		3,891,188	
Value/Ac-ft.	$2,145	$2,525	$734	$912	$1,225	$2,201

[a] Source: Amosson & Guerrero, 2014
[b] Source: Amosson et al., 2014

Feed grains include corn, corn silage, sorghum, and sorghum silage while small grains include barley, oats, rye, triticale, and wheat. In comparison to these industries, cotton's water use is less than either small grains or feed grains and the value per acre-foot of water applied to cotton is greater than either category. Feed grains and small grains have more acres planted than cotton resulting in a higher total water use. Furthermore, cotton's production value per acre-foot of water applied is higher than either feed or small grains as the profit margin for cotton is lower resulting in a higher cycling of money back through the economy. Feed grains have a higher profit margin from production resulting in an increase of money the producer can divert for his own purposes (savings, retirement, investments, or other spending outside of the region) instead of additional spending in the local economy. However, when considering production and processing, the value of water per acre-foot for feed grains is almost as high as cotton. This is caused by the differences in the regional forward linkages of feed grains and cotton. Specifically, the higher value from production and processing of feed grains is a result of the livestock industry utilizing feed grains within the region for livestock rations. In contrast, the majority cotton production and processing is exported to foreign countries and only a small amount is processed by regional industries. This summary is not a definitive measure; however, it can be used as a basis for determining the value of water when it is used for different agricultural commodities.

In addition to analyzing the value of water from agricultural commodities, land values can be used as a measure of water valuation. Texas Rural Land Value Trends (2014) portray the value that water adds to the land. Focusing on the Texas Panhandle and South Plains Regions, dry cropland ranges from $500 to $1,000 per acre, while irrigated cropland with good water ranges from $1,600 to $4,000 per acre, and irrigated cropland with fair water ranges from $1,200 to $2,250 per acre. Variations in the value of irrigated cropland could come from soil quality, topography, etc. however the overall trend indicates that water increases agricultural land value. The additional value that water contributes to an irrigated producers' profits assists in the repayment of any debt incurred from their operations. While water conservation efforts are necessary to extend the usable life of the Ogallala Aquifer, producers lack incentives to actually conserve water as it could hinder their ability to pay back loans. Therefore, conservation needs to be an attractive option for the producer with an incentive program in place that will aid in water conservation while providing supplementary compensation that will allow producers to repay debt.

Increased producer profitability, differences in land value, and overall regional economic benefits from water use is beneficial to today's generation of agricultural producers. However, future generations of farmers may not have the ability to draw groundwater to irrigate their crops or increase their land value. While the main goal of water policies is to manage the decline of the Ogallala Aquifer in order to extend its usable life, eventually, certain portions of the aquifer will be exhausted, creating the need for alternate production methods for future producers to practice. This conclusion is the driving force behind sustainable agricultural practices.

5.5 Sustainable Agriculture

When discussing water valuation, water policy, and their effect on producers of agricultural goods, the concept of sustainable agriculture must be included. Underlying sustainable agriculture are three main goals: environmental health, economic profitability, and social and economic equity. These goals are components of intergenerational equity or the idea that "the current generation must not compromise the ability of future generations to meet their material needs and to enjoy a healthy environment" (Debertin & Pagoulatos, 2015). This concept places an obligation on the current generation of agricultural producers. They should consider implementing production practices and farming systems that will not risk future generations' ability to produce agricultural commodities while simultaneously maintaining a sufficient standard of living for themselves. Sustainable agricultural practices can be divided broadly into the following categories: farming and natural resources, plant production, livestock production, and economic, social and political effects.

Farming has an impact on natural resources including water, energy, air, and soil. Water resource management in regards to farming includes improving farm operation practices that allow for the improvement of water conservation, as well as providing incentives for producers to implement the use of plant drought-tolerant crops, reduced volume irrigation systems, and improved crop management to reduce water loss. Energy management in a sustainable environment includes the adoption of renewable sources in place of non-renewable energy, however, only to the extent that is economically feasible.

Air and soil quality has need for improvement: air through the reduction of agricultural produced pollution and soil through a reduction in erosion and increase fertility.

Plant production practices in sustainable agriculture vary depending on the region under consideration. Several diverse factors including topography, soil type, climate, and the producer's overall production goals must be taken into account before a plant production practice can be implemented. While these factors influence crop production on an individual basis, there are several common factors that can assist producers with the goal of a sustainable farm system. These common factors include: diversifying crops produced, soil management, and the efficient use of inputs.

Individual livestock production practices also face similar diverse factors. However, there are broad elements that every producer must consider when implementing a sustainable livestock operation, despite their individual system. First, the appropriate livestock to produce must be selected. Livestock selection depends on an individual producer's resources, however, when developing and implementing a livestock system; it should be one of the first decisions made as the following variables are dependent on livestock choice: animal nutrition, reproduction, health of the herd, grazing, and confined livestock production.

Lastly, the economic, social, and political aspects of sustainable agriculture must be considered. When determining the success of a sustainable system it is these factors that will ultimately make or break the sustainable agriculture system as they pertain to policy, land use, labor, and rural community development (Bradford, et al., n.d.).

The burden of creating and implementing the above production practices should not rest solely with agricultural producers. Instead, producers, policymakers, and agricultural experts should work together to create sustainable farming practices tailored to specific regions, in an attempt to satisfy intergenerational equity. The valuation of water in these critical decisions is extremely important. It is not only the producer's that need to practice water conservation today, but agronomists that need to advance the technological and genetic aspects of drought tolerant crop varieties that will allow for the continuance of agriculture in the region and promote economic stability when groundwater is no longer available.

In addition, researchers and policymakers need to be proactive in developing and implementing alternate production systems, as their economic viability will need to be tested before producers will consider their adoption. Integrated crop-livestock systems are one such alternate production system, as producers' transition from the current fully irrigated production systems to dryland production. While this approach may be an opportunity for some producers in the region, there are some who will not be able to logistically adopt such a system and other production methods will need to be developed. The evidence for an eventual discontinuance of the Ogallala Aquifer for large-scale irrigation is apparent. To prepare for this event, alternate strategies should be in place to ease the transition from traditional production methods to new systems with the objective of maintaining the economic stability of the region.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The Ogallala Aquifer is an important resource to the Great Plains Region of the United States. Its groundwater is used to irrigate one-fifth of all cropland in the country and over 90 percent of the water withdrawn from the aquifer is used for agricultural purposes. This high usage rate has led to decreasing saturated thickness, especially in the southern portion of the Aquifer where withdrawal rates greatly exceed recharge. The Southern Ogallala Region supports major agricultural industries that are integral components of the regional economy. While the economic benefit provided to the region by these industries cannot be overlooked, local leaders are concerned that these benefits do not outweigh the negative impact associated with the high rate of groundwater use and subsequent decline in the water table that threatens the future economic viability of the region. Research focused on the regional economic impact of agricultural industries is an important element in the evaluation, creation and implementation of water conservation policies aimed at managing the decline of the Ogallala Aquifer while minimizing the impact on the regional economy.

This study focused on analyzing the regional economic impact and water use of the cotton industry in the Southern Ogallala Region by addressing the following specific objectives:

1. Determine the water usage of the cotton industry in the Southern Ogallala Region,
2. Estimate the regional economic value of the cotton industry in the Southern Ogallala Region,
3. Create a basis for the evaluation of the regional economic value of cotton production per unit of water used. This information will aid regional policymakers when considering and implementing future water policies, and,
4. Increase the understanding of the value of water as an economic good and its effect on producer's incentives and sustainable agriculture.

Cotton production has been a component of the Southern Ogallala Region's economy for over 150 years. Historical cotton planted acreage has fluctuated widely in terms of irrigated and dryland acreage over the past 40 years. Irrigated cotton acreage has reached a high of 2.2 million acres planted and a low of 1.2 million acres planted. Production from irrigated acreage has been more erratic than acres planted, with a high of 3.7 million bales being produced from 1.9 million acres planted in 2005 to a low of 500,000 bales produced from 1.6 million acres planted in 1992. Dryland cotton acreage planted and production has seen similar fluctuations to that of irrigated cotton. Dryland cotton acres planted reached a high of 2.4 million acres and a low of 1.1 million acres.

Dryland cotton production has ranged from 2 million bales produced from 1.6 million planted acres in 2007 to 225,000 bales produced on 1.8 million acres planted in 1998. In 2014, 1.6 million acres of irrigated cotton were planted with a resultant production of 2.4 million bales while 2.2 million acres of dryland cotton produced 960,000 bales. Cumulatively in 2014, total cotton acres planted exceeded 3.8 million acres with a total production of 3.3 million bales.

Total irrigated cotton production in the Southern Ogallala Region was reported by the National Agricultural Statistics Service to be over 1.1 billion pounds of cotton lint and over 800,000 tons of cottonseed in 2014. With the assumption that 1,250 pounds of lint are produced for every acre-foot of irrigation applied, the estimated total water use for the cotton industry in the region was 903,708 acre-feet. The majority of water use for irrigated cotton production occurred in the Texas High Plains, 884,390 acre-feet of water or 97.9 percent of the total cotton water use in the region. When considering all major crop and livestock sectors of the regional agricultural industry and their respective water needs, total water consumption of agricultural commodities surpassed 7.1 million acre-feet for 2014. Irrigated corn accounted for the highest water use at 56.5 percent, followed by wheat (12.9 percent) and cotton (12.6 percent).

The direct sales that resulted from irrigated cotton production were valued at over $770 million for cotton lint and $190 million for cottonseed. With the addition of dryland cotton lint and cottonseed, the total value of direct sales exceeded $1.3 billion. Dryland cotton production sales were included in the direct value estimation as it contributes to the regional economy without affecting water use. The value generated from the processing sector of the cotton industry—namely oilseed mills, tailoring and alteration stores, signage shops, and CLOs (cattle feedlots and dairies)—contributed $320 million in direct output relative to cotton production. The combination of production and processing sales resulted in a total direct output of almost $1.7 billion for the cotton industry.

When considering the backward-linked production sectors of irrigated cotton, the regional economic contribution was estimated at $1.9 billion with the support of 16,000 jobs. Dryland cotton production generated $900 million and provided around 7,900 jobs. Therefore, the regional economic contribution of cotton production for 2014 was valued at $2.8 billion with an estimated 24,000 jobs. Cotton processing contributed an additional $484 million in economic activity and 2,100 jobs to the regional economy. Considering both the production and processing sectors, the cotton industry generated over $3.3 billion to the regional economy and provided 26,300 jobs.

The economic impact of cotton production gauged with the amount of water used for production resulted in a valuation of the water at $2,145 per acre-foot. When the combined economic impact of cotton production and processing was considered, the value of water increased to $2,525 acre-foot. These values are significant to this study as they allow for a snapshot of the value of water per acre-foot for cotton production and processing in the region. Calculating this value creates a basis of comparison to other agricultural commodities produced in the region. It must be noted that this measurement should not be the only criteria for judging the value of agricultural commodities as additional factors must be taken into consideration.

The eventual decline of the Ogallala Aquifer will result in most of crop production converting to dryland. Although government support programs for monoculture production, current operating systems, and a general sense of sentiment for traditional production systems are prevalent in the region, the fact remains that the aquifer will eventually decline to a point where it is no longer available for large-scale irrigation. With this result in mind, developing a sustainable production system is imperative to preserve the livelihood of agricultural producers and the economic viability of the region. A lack of agricultural production from the Southern Ogallala Region will have detrimental effects on both the local and national economy. An increasing national population places additional pressure on producers to provide food and fiber to sustain growing numbers and if agricultural production in any region were to be diminished significantly, there will be harmful consequences.

While this study provides a foundation for understanding the economic contribution of the cotton industry to the Southern Ogallala Region, there are two limitations of this study that must be noted. First, a portion of the value of irrigated cotton could have been generated by dryland cotton and therefore is not completely derived from irrigation alone. If the dryland crop alternative for cotton was known for certain, in theory, this value could be partitioned out to only get the value that is derived from irrigation. However, individual producers will incorporate differing dryland alternatives into their production mix, depending on what is the most favorable in terms of production and economics, and there is no way to determine which crop will be produced. Thus, in order to make comparisons between the value of water in producing commodities, a total value (dryland and irrigated) was included to create an even evaluation between crops.

The second limitation is that a three-year average price was used for a point in time valuation estimate. Averaging the price allowed for any fluctuations over the time period to be smoothed out, and therefore, is an asset to this study. The limitation lies in using the point in time production estimate from 2014. Utilizing the estimate from a single year does not allow for the reflection of climactic conditions, policy changes or any other variables that could affect production numbers and, therefore, could not be used as a representation of past or future trends. This study depicts the economic contribution of the cotton industry in 2014 but could be manipulated to provide a basis for future trends.

In an effort to maintain the Great Plains Region as an important agricultural area, researchers, producers, and policy makers must work together to form a sustainable production environment that will support future generations of agricultural producers. The results of this study in combination with research will provide the basis for future production systems. The agricultural industry in the Southern Ogallala Region will realize drastic changes as the Ogallala Aquifer declines to levels that will not allow for sustained large-scale irrigated agriculture. The future of the economic viability of the region is dependent on the ability to adapt to changing environmental conditions. Further research is necessary but the initial prognosis indicates that improvements on the current rate of water consumption are possible and would allow the management of the decline of the aquifer while alternate production systems are adopted to allow for the continuation of a profitable agricultural sector in the region.

APPENDIX A

COTTON PRODUCTION AND PROCESSING VALUE BY STATE

Table 11. Economic impacts of the cotton industry in the area of Colorado located in the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$-	$-	$-	$-
Value Added	$-	$-	$-	$-
Employment	$-	$-	$-	$-
	Cotton Processing			
Output	$13,798,316	$7,138,317	$1,018,260	$21,954,893
Value Added	$2,768,366	$2,361,767	$580,943	$5,711,075
Employment	44	32	10	86
	Total Cotton Industry			
Output	$13,798,316	$7,138,317	$1,018,260	$21,954,893
Value Added	$2,768,366	$2,361,767	$580,943	$5,711,075
Employment	44	32	10	86

Table 12. Economic impacts of the cotton industry in the area of Kansas located in the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$3,924,143	$3,213,273	$826,309	$7,963,725
Value Added	$1,086,076	$1,425,05	$478,628	$2,989,755
Employment	30	30	7	67
	Cotton Processing			
Output	$77,762,641	$38,589,544	$5,653,893	$122,006,078
Value Added	$16,967,259	$12,823,815	$3,225,692	$33,016,766
Employment	253	173	54	480
	Total Cotton Industry			
Output	$81,686,784	$41,802,817	$6,480,202	$129,969,803
Value Added	$18,053,335	$14,248,866	$3,704,320	$36,006,521
Employment	283	203	61	547

Table 13. Economic impacts of the cotton industry in the area of New Mexico located in the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$16,115,882	$13,218,013	$3,397,765	$32,731,660
Value Added	$4,442,187	$5,865,084	$1,968,103	$12,275,374
Employment	123	123	29	275
	Cotton Processing			
Output	$35,258,262	$13,405,928	$2,339,119	$51,003,309
Value Added	$12,124,965	$4,571,267	$1,334,548	$18,030,780
Employment	127	60	22	210
	Total Cotton Industry			
Output	$51,374,144	$26,623,941	$5,736,884	$83,734,969
Value Added	$16,567,152	$10,436,351	$3,302,651	$30,306,154
Employment	250	183	51	484

Table 14. Economic impacts of the cotton industry in the area of Oklahoma located in the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$2,718,358	$2,198,542	$567,033	$5,483,933
Value Added	$775,416	$971,169	$328,451	$2,075,036
Employment	21	20	5	46
	Cotton Processing			
Output	$6,889,489	$3,681,672	$538,839	$11,110,000
Value Added	$1,274,527	$1,219,180	$307,418	$2,801,125
Employment	22	17	5	44
	Total Cotton Industry			
Output	$9,607,847	$5,880,214	$1,105,872	$16,593,933
Value Added	$2,049,943	$2,190,349	$635,869	$4,876,161
Employment	43	37	10	90

Table 15. Economic impacts of the cotton industry in the area of Texas located in the Southern Ogallala Region, 2014.

	Direct	Indirect	Induced	Total
	Cotton Production			
Output	$1,329,630,374	$1,166,779,900	$295,292,940	$2,791,703,214
Value Added	$302,278,435	$528,455,219	$171,029,571	$1,001,763,225
Employment	10,114	11,144	2,550	23,808
	Cotton Processing			
Output	$186,284,123	$69,848,347	$21,767,806	$277,900,276
Value Added	$64,195,163	$25,906,357	$12,418,069	$102,519,589
Employment	728	353	209	1,290
	Total Cotton Industry			
Output	$1,515,914,497	$1,236,628,247	$317,060,746	$3,069,603,490
Value Added	$366,473,598	$554,361,576	$183,447,640	$1,104,282,814
Employment	10,842	11,497	2,759	25,098

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