IMPACTS OF THE EXPANDING DAIRY INDUSTRY ON THE TEXAS HIGH PLAINS

by

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ABSTRACT

The dairy industry in the Texas High Plains has undergone rapid expansion in the past two decades, growing from 12,066 head in 2000 to 262,622 head in 2015. This growth is due to establishment of new dairies as well as migration of dairies from other states. Many factors contributed to this growth, including availability of land, lower input prices, and a less stringent regulatory environment.

Dairies use water both directly through drinking and facility maintenance and indirectly through irrigation of crops used for feed. It was hypothesized that overall water use and crop composition in the study region changed in response to the increased demand for silage from the dairies. Silage must be produced locally since the high moisture content makes it difficult and expensive to transport. The source of water for irrigation is the Ogallala Aquifer. This has caused concern as the aquifer is being depleted faster than it can recharge.

It was also hypothesized that dairies are generating economic value through supporting businesses for production inputs as well as processing facilities that have been established in the region. No existing literature examines the localized economic impact of dairies across specific types of businesses. The specific objectives of this study were to assess the impacts of the expansion of the dairy industry on water usage, crop mix, and business composition (including type, employment, number of establishments, and

income). In addition, projections for dairy growth were used to estimate water use changes 10, 20, and 30 years in the future.

Data from the beginning of the expansion period in 2000 were compared to the most current data (2015) in order to detect any changes that occurred. Irrigated crop data were collected from the Farm Service Agency (Farm Service Agency, 2018) and data on businesses were collected from the US Census Bureau’s County Business Patterns (County Business Patterns, 2017). In addition, a spatial analysis was conducted to examine how the location of dairies has impacted the study region.

Results indicated that the regional crop composition increased in silage acres as did associated water usage across the study period. However, total irrigated acres decreased during this time; therefore, silage production displaced other crops such as feed grains. Several industry sectors showed increases in employment and number of establishments, such as construction, transportation, and animal slaughter. More houses are needed for additional workers employed by dairy processing facilities, milk and dairy products need to be transported to and from processing facilities, and slaughter facilities have expanded from the increase in dairy cull cows.

In summary, the overall change in the region due to dairy expansion was an increase in silage acres, which generates higher value for the water pumped when compared to crops grown for grain. However, total irrigated acres in the study region declined, indicating the increase in irrigated acres for feed for dairies was offset by a decrease in irrigated grain acres. In addition, dairies have increased the number, size, and employment of related business establishments locally, which has increased the economic activity in these rural areas. Projections indicate that growth will continue at a slower rate in future years. Thus it can be expected that the dairy industry and other supporting sectors will continue to be a major contributor to rural economies.

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CHAPTER I

INTRODUCTION

The dairy industry's history in the state of Texas began with small, localized production. In the 19th century, most milk and milk products such as butter and cheese did not travel far from the farm where it was produced. The 20th century saw significant population growth, which created an increased demand for milk and other dairy products. Combined with the advent of pasteurization technology, this resulted in significant growth of the dairy industry. Considerable change occurred within the industry in the 1930s with the establishment of processing plants and distribution centers. By 1939, 228 dairy-product processing plants existed in Texas, with production concentrated primarily on the east side of the state. Throughout the 1930s, growth continued in both demand and number of dairy cows. However, the 1940s and 50s brought significant challenges to the industry. Milk was imported from the dairy-producing states of Wisconsin and Minnesota as transportation became less expensive, which drove Texas milk prices down. This led to consolidation of small producer organizations into larger multimarket associations (Odom, 2010).

The structure of the dairy industry in Texas changed again after World War II. In 1945, there were 1,594,000 dairy cows in the state of Texas. By 1971, the inventory had dropped to 355,000 head. The number of dairy cows along with the overall number of producers continued to decline in the following years, but the rate slowed significantly. The amount of milk produced in Texas modestly decreased from 3,750,000 pounds in 1948 to 3,680,000 pounds in 1982 despite smaller herd sizes, as a result of increased production efficiency (Odom, 2010). Improved herd management techniques, such as changes in feed rations and more rigorous genetic selection measures, allowed producers to harvest more milk per cow and compensate for the decreasing herd numbers (Schulte, 2009).

Around 2000, the concentration of dairies began shifting toward the Texas High Plains. Several factors influence the location of a dairy, including weather, proximity to human populations, labor availability, environmental regulations, and profitability. As population centers continued to grow, dairies often relocated to more rural areas. It was no longer necessary for dairies to be located close to where consumption occurs with lower transportation costs. It became more common to produce milk in areas with lower production costs and ship the dairy products to the consumers in other locations (Schulte, 2009). The affordability of land encouraged the relocation of many existing operations from eastern Texas and the establishment of new dairies in the Texas High Plains. Greater land availability allowed producers to expand their operations to benefit from economies of scale. By increasing herd size, producers were able to reduce their costs per cow, therefore increasing their overall profitability (Schulte, 2009).

The Texas High Plains has also attracted dairies from other states. California is the nation’s top dairy producing state with over 1.7 million dairy cows in 2016 (California Department of Food and Agriculture, 2016). However, a new law in California that was passed in 2016 requires methane production tied to dairies be reduced by 40 percent from 2013 levels by the year 2030 (Khan, 2017). While some producers are attempting to adapt to this new regulation, many producers find such a requirement is impossible to meet. Land values are also increasing in California, reducing the amount of land devoted to growing feed. Over 600 dairies have gone out of business and almost half of those cows are being sold out of state, rather than remaining local (The Business Journal, 2016). Dairy producers are relocating to regions that are less prohibitory to their operations as environmental regulations become stricter in high population centers like California. The Texas High Plains is more favorable to dairy producers due to a less stringent regulatory environment and affordability of land.

The development of irrigation technology also facilitated migration to the Texas High Plains. Even though this area is classified as a semi-arid region, irrigation allows high water use crops to be grown. The Ogallala Aquifer is one of the largest aquifers in the world and serves as the primary source of water for irrigation in the region. It averages 200 feet of saturated thickness, but can range from less than one foot to 1,300 feet depending on the location (Guerrero, Amosson, and Jordan, 2012). The development of irrigation in the Texas High Plains occurred primarily during the mid-1940s through the 1950s. Producers' perception of the aquifer as an unlimited supply of water resulted in a large increase in number of wells during this time. By 1980, there were 3.9 million irrigated acres in the Texas High Plains and approximately 75,000 irrigation wells (Weinheimer, 2008). Irrigation began to plateau after that and then decline in recent years as it became clear the aquifer was being depleted faster than it could recharge and maximum pumping capacity had been reached. In 2015, there were 4.1 million irrigated acres in the Texas High Plains (Farm Service Agency, 2018). Irrigation created a thriving agriculture industry, with the availability of feed grains leading to the development of fed beef operations in the 1960s. The rapid expansion of feedlots created more demand for grain than could be produced locally in the Texas High Plains, causing the region to become grain deficient by the 1970s and forcing reliance on grain imports. Confined swine feeding operations, which became prominent in the 1990s, only added to the grain deficit (Guerrero, Amosson, and Jordan, 2012).

Local crop production is especially important for dairy producers because dairy rations contain more silage than a typical feedlot cattle operation, which relies more on grains. An average dairy cow ration consists of approximately 92 pounds of silage as fed daily, which accounts for 70 percent of the total daily feed requirements (Jordan, 2011). Since silage is more difficult to transport over long distances due to the higher moisture content, it must be grown close to where the dairies are located (Guerrero, Amosson, and Jordan, 2012). In addition to the indirect water use through feed production, dairies use water directly for drinking and facility maintenance. The amount used varies by facility type, herd size, and management techniques, but industry specialists have estimated that dairies use approximately 65 gallons of water per cow per day (Amosson, Marek, and Hillyer, 2017). Guerrero, Amosson, and Jordan (2012) estimated the total water use (direct and indirect) of the dairy industry in the Southern Ogallala Region in 2010 to be 1,592,670 ac-ft.

Establishment of complementary businesses such as dairy product processing plants has helped support the industry. In 2005, Southwest Cheese opened in Clovis, New Mexico due to the existing presence of a well-developed dairy industry. Several other sites located in Texas were also considered; however, it was determined that the region did not produce enough milk to supply a plant of that size and transportation costs for additional milk to compensate for the deficit would be too high. In 2009, Southwest Cheese underwent an expansion that increased plant capacity by 40 percent. A second expansion occurred in 2016, further increasing its production capacity. Today, the plant processes over 220 truckloads of milk or 10.5 million pounds daily and approximately 44,000 pounds of cheese per hour, making it the largest single site cheese plant in the world (Southwest Cheese Production Facility, 2018).

Shortly after the establishment of Southwest Cheese, another cheese plant was founded in the Texas Panhandle. In 2007, Hilmar Cheese opened in Dalhart, Texas. The plant was initially able to process 250,000 gallons of milk and produce half a million pounds of cheese daily. As the plant expanded, processing capacity rose from two million to 9.5 million pounds of milk per day by 2014. This increased production capacity led to an increase in the demand for milk for processing purposes. When the Hilmar plant first began operation, milk was supplied by ten independent dairies with cow inventory totaling 36,000 head. In 2017 with Hilmar's increased production capacity, the plant was supplied with milk from more than 150,000 dairy cows (Hilmar Cheese Plant, 2017).

In addition to Hilmar Cheese, other dairy processing plants have settled in the Texas Panhandle. Pacific Cheese is a broad line cheese supplier that cuts, packages, and distributes cheese and is located in Amarillo, Texas. Other fluid milk processors have also been established in the region such as Plains and Gandy's (Guerrero, Amosson, and Jordan, 2012).

The establishment of these dairy processing plants has widespread economic implications. In an economic impact report regarding the establishment of the Hilmar

Cheese plant, it was found that this plant would spark economic growth in both the dairy industry as well as other related industries. The report was conducted by The Perryman Group of Waco, Texas, which was hired by the High Plains Dairy Council. The report anticipated the plant would add 300 direct jobs with an annual payroll of $10 million. The Perryman Group predicted that Hilmar's expansion would result in more dairies coming to the region and the addition of another 2,400 jobs. The total number of permanent workers in other related businesses associated with the cheese manufacturing facility was expected to reach 11,050 as the plant matured. The total economic impact was forecasted to be $13.66 million at the local level and $44.77 million across the state (Perryman, 2005).

These favorable conditions in the High Plains such as the warm and dry climate, availability of land, stable regulatory environment, feed production capabilities, and proximity to complementary businesses have led to an increase in the number of dairy producers and overall number of cows. In the Texas High Plains, inventory numbers have escalated rapidly, with the number of head growing from 12,066 to 262,622 over a fifteen year period from 2000 to 2015; production has likewise increased from over 20 million pounds of milk in 2000 to 640 million pounds in 2016 (Federal Milk Marketing Order 126, 2017). Dairy processing plants have continued to expand in recent years, indicating further growth in the dairy industry. This continuing expansion will have far reaching impacts across the Texas High Plains Region and the state.

It can be expected that as the dairies expand, crop composition will change with more silage crops being grown to meet the increasing demand. Therefore, water use from irrigation will increase for the dairy industry. It is also anticipated that industry growth in other related sectors will be observed as a result of the dairies expansion. Furthermore, this study seeks to use projected dairy inventory numbers to predict changes in water usage 10, 20, and 30 years in the future. Specifically, the objectives of this study are to assess the impacts of the expansion of the dairy industry on:

- water usage,
- crop composition, specifically forage demand, and
- business composition (including type, employment, number of establishments, and income).

CHAPTER II

LITERATURE REVIEW

The purpose of this section is to review existing studies that relate the impact of an industry on both the economy and on water usage. Since current literature that analyzes the dairy industry at a localized level is limited, this literature review examines studies that evaluated other industries or used similar methods as what is used in this study. This literature review has been delineated into the following categories: 1) regional economic assessments, 2) water conservation, and 3) spatial analysis.

Regional Economic Assessments

Economists are often interested in the effects an industry will have on the surrounding economy as a whole. Economic assessment studies are used to estimate the impact of an industry to the economy in a defined area. Changes in revenues generated, value-added, and employment are often measured to evaluate an industry's impact

The objective of a study performed by Nalley and Tack (2015) was to determine the economic impact of hybrid rice in the Mid-South. The specific objectives included estimating: 1) yield gains associated with adopting hybrids; 2) total revenue gains from the adoption of hybrids; 3) total value added as a result of the additional rice produced from hybrids, using IMpact analysis for PLANing (IMPLAN); and 4) profitability difference between hybrid and non-hybrid varieties of rice. Multiple regression analysis was used to formulate a model to predict yield given weather, year, and varieties. Results suggest that yields estimated from the model line up with RiceTec™'s advertising claims regarding yield benefits from their hybrids. The revenue gained from growing hybrid rice is calculated by taking the percentage of hybrid rice out of total rice production multiplied by the increased yield levels then multiplying this by the price of rice. The total gain across all states in the study region across the entire study period, with various statewide adoption rates that depended on the year, was $915,337,828. IMPLAN was used to estimate that hybrid varieties created an additional benefit of $16.39 million in value-added production to local economies. While hybrids have been shown to increase revenue, it is also important to see if profitability is improved, as hybrid varieties have more expensive seed prices. Ten-thousand simulated yields were generated for both hybrids and conventionals under average weather conditions. A per-acre profit function was constructed (price times yield, minus costs) and applied to each of the 10,000 iterations. In Arkansas and Mississippi, hybrids were shown to be more profitable than conventionals 100 percent of the time, proving that the higher seed costs are offset by additional revenue generated from increased yields when using hybrids.

Guerrero et al. (2011) conducted a study on how ethanol production affects the economy in the Texas High Plains as well as how it influences water usage in the area. IMPLAN was used to quantify the effects of construction and operation of an ethanol plant on the regional economy. Specifically the study focused on the changes in the regional economy due to an increase in the demand for inputs such as feedstock, water, and energy used in the operation of an ethanol plant. Direct, indirect, and induced effects were generated from the model, using input data collected from ethanol plants. Multipliers that estimate total economic impact of expenditures within an economy were produced by the model. The results show that the ethanol plant in this study has impacted the regional economy through construction expenses and operational input costs, which in turn created additional jobs and industry output. The impacts reach far beyond the scope of the single plant. They concluded the total impacts from the ethanol plant, including direct output, value-added, and employment, are significantly higher than the total impacts from irrigated crop production requiring equivalent amounts of water.

Leistriz (1993) looked at the economic impact of the dairy industry in North Dakota using an input-output model to estimate regional economic impacts. Dairy enterprise budgets were used to estimate inputs for the model and the potential expansion level of the industry was determined by the capacity of the state's milk processing facilities. Leistriz found that certain sectors, such as agriculture, finance, insurance, and real estate, would receive higher direct benefits. Overall, indirect and induced impacts were more than twice the direct impacts. Leistriz concluded additional jobs would be created and more state tax revenue would be generated.

Stevens et al. (2008) focused on the economic contributions of dairy farming in the Southeast United States. The estimation of these contributions was based on the standpoint of economic loss that would be incurred should the dairies cease to exist. An input-output model, IMPLAN, was used in this analysis. The types of impacts considered were output, value-added, labor income, property income, indirect business taxes, and employment. These could all occur through direct, indirect or induced effects. Data was collected from various sources, including the USDA census, enterprise budgets, and

Bureau of Labor Statistics. Both the contributions of dairy farming and dairy product manufacturing were considered in this analysis. They estimated that the dairy industry contributed $8.5 billion in total economic output, $2.8 billion in value-added production, and 49,000 jobs. Stevens et al. concluded that dairy farms and dairy product manufacturing firms are a significant component to the Southeast United States economy.

Water Conservation

Irrigated agriculture is vital to the Great Plains Region. However, the Ogallala Aquifer, which is the primary source of water for the irrigation, is being depleted faster than it can recharge. There is growing concern regarding current water use levels in the Ogallala Aquifer region. A number of studies have examined the effects that various water conservation efforts and policies would have on the aquifer itself as well as the regional economy.

Wheeler et al. (2006) focused on the cost of water conservation in the Southern High Plains of Texas. The objective of this study was to analyze and evaluate the impacts of selected water policies on the Ogallala Aquifer, compared to an unconstrained baseline scenario. Three water conservation policies that limit drawdown were analyzed: 1) compensating producers for decreasing water usage resulting in zero drawdown relative to the amount that would have otherwise been used over sixty years, 2) limiting water usage to limit drawdown to 50 percent of water that would be used in absence of policies, and 3) limiting water usage to limit drawdown to 75 percent of what would have been remaining in the aquifer without a policy over sixty years. An optimization model was used with the objective to maximize net present value (NPV) of producers' net returns.

Wheeler et al (2006) found that results of the baseline in comparison to the policy alternatives show generally consistent trends. Cost is a direct related to saturated thickness depletion and NPV for each scenario. When little depletion occurs, then implicit cost for conserving a foot of saturated thickness is relatively high. Conversely in high water use scenarios, the implicit cost for an additional foot of saturated thickness is much lower. Another finding in this study is that marginal costs increase as conservation goals increase. The cost of a zero drawdown policy is much higher than the cost for both the 50 percent and 75 percent drawdown policies. Overall, the results suggest that the policy impacts vary greatly by region. The highest restrictive policy at a zero drawdown rate conserved the most water but had major negative impacts on NPV and economic activity. Such a restrictive policy is not necessary in most counties in the study region. It would have too many detrimental effects similar to complete aquifer depletion, which is what the policies are trying to circumvent. In many counties the 75 percent and even the 50 percent drawdown restrictions were not binding constraints because the levels of saturated thickness did not decrease to those levels. But these policies did show conservation of water and a resulting decrease in NPV when compared to the unconstrained baseline. These policies were the most restrictive on high water use counties. The study shows that blanket policies are not effective. Wheeler et al. states that water conservation policies should be focused on higher water use counties where the implicit costs would be lower per foot of saturated thickness and the costs of implementing such policies would be worth the water conserved.

Johnson et al. (2004) focused on the trade-off between the value of using water now and the value of being able to use water in the future in the Ogallala Aquifer. The objectives of this study were to: 1) estimate the economic life of the aquifer across the region under different water conservation scenarios, 2) identify water conservation policy alternatives to extend the life of the aquifer, and 3) evaluate the regional economic impact of the implementation of the various water conservation policy alternatives. Dynamic optimization models were used to estimate the economic life of the aquifer under the different policy scenarios. The models were used to estimate the optimal level of water extraction for irrigation and the resulting net present value of net returns over the planning period of 50 years. Groundwater conservation districts in Texas have the authority to utilize the instruments of assigned quotas or pumping rights as well as extraction fees or taxes on withdrawals. Therefore the policies considered in this study included: 1) a production fee of $1 per acre-foot pumped, 2) an annual restriction of water use to 75 percent of a 10 year average water use, and 3) a restriction on the drawdown of the aquifer to 50 percent of the initial saturated thickness at the start of the 50 year planning period. These policies were compared to a baseline scenario where no changes to water conservation policy were considered. The objective function in these models was to maximize the net present value of annual net returns. The results of these models were then used in an input-output model to determine the regional economic impact of the three water conservation policies. The data entered into the input-output model was the change in gross revenue from the baseline scenario for five different commodities as a result of the change in water policy.

Johnson et al. (2004) found the scenario that considered a fee of $1 per acre-foot pumped demonstrated little change from the baseline scenario. The number of irrigated acres did not show a significant change, resulting in only a 3 percent decrease by year 50.

The policy that restricted annual water use resulted in an immediate decrease in both water use and crop revenue. Level of saturated thickness was estimated to increase 30 percent from the baseline, but the net present value of the net income per acre was the lowest of all three policies considered at approximately 15 percent below the baseline. The final scenario that looked at restricting the drawdown of the aquifer to 50 percent of initial levels resulted in similar ending levels of saturated thickness as the annual water use restriction scenario. However, net present value only decreased by six percent compared to the baseline. The authors concluded that this method allows for the producers to have greater flexibility to use the water in a manner similar to the baseline early on in the planning period but then proceeding in a slower transition to more conservative water use in crop production. The study concluded the policy that restricts drawdown to 50 percent of the initial saturated thickness levels is the most effective, as it saves the most water with the smallest cost to the regional economy. It also allows producers to increase irrigation during periods of drought and reduce irrigation in years with increased rainfall. The other two policies would incur significant costs associated with monitoring water withdrawal from each well. The production fee approach was shown to not have a large effect on water use. The $1 fee is not sufficient to impact a producer's decision with respect to water levels applied to the crops. Johnson et al. believes a much higher fee would be necessary for this type of policy to be effective in reducing irrigation levels.

Osborn (1973) conducted a study evaluating the economic effects of the depletion of the Ogallala Aquifer on the Texas High Plains Region. The analysis considered 42 contiguous counties in the region from the time period of 1970-2020. An input-output analysis was conducted to determine the inter-industry effects of an exhaustible irrigation water supply on income and employment for each decade of the study period. The benefits estimated from this model were based on the increases in economic activity that occur when irrigation was applied to dryland. Irrigated acreage was projected to increase until 1980, and then was expected to decrease over time until 2020. The benefits of irrigation from both employment and income were broken down in to direct, indirect, induced, and total benefits. Benefits increased until 1980, when irrigated acreage was at its peak, before declining until 2020. Osborn concluded that groundwater used for irrigation is an important input in the agriculture industry and contributes to overall economic growth. As the aquifer is depleted, the regional economy will also decline. He believes that the eventual exhaustion of the aquifer is inevitable and that water conservation management strategies will only temporarily prolong the life of the aquifer.

Dairies use large amounts of water in their operations, both directly and indirectly. Silage consumption contributes to a large portion of the indirect water use. Almas et al. (2017) examined the effect of silage quality on both milk production as well as water conservation potential. As dairies continue to grow in the Texas High Plains region, the quantity of silage demanded rises as well in order to sustain these businesses. Irrigation plays a major role in silage production. Historically, corn silage has been the dominant feed preferred by dairies; however, it is a high water use crop. Sorghum silage has been identified as an attractive alternative, as it supplies almost equal nutritional value when compared to corn silage and requires about one-third less water. The objective of this study was to predict the effect of forage quality of corn and sorghum silage on milk yield. Ordinary least squares regression was used with milk yield as a dependent variable and crude protein, lignin, starch, and in-vitro true digestibility as explanatory variables. The results reveal that there is a statistically significant relationship between forage quality and the amount of milk produced per ton of forage dry matter. This held true for both corn silage and sorghum silage. More milk is produced when corn silage is fed; however, corn silage is more expensive than sorghum silage per ton. Furthermore, when the cost of irrigation is considered, corn silage requires more water. The results show that it is more profitable to feed cows with sorghum silage, despite the lower forage quality and the additional tons needed to meet the same energy requirements. Additionally, less water is pumped from the aquifer, which saves water for future use. More education will be required to encourage producers to choose sorghum silage over corn silage, since corn silage is the preferred feed in the region.

Ho et al. (2005) examined how changing water prices and availability would impact irrigated dairy farms in Victoria, Australia. Two case study farms were considered in this paper, a ‘water-reliant’ farm and a ‘fodder-reliant’ farm, and various scenarios were tested. Water price was examined at four levels, a base price and increases of 50 percent, 100 percent, and 200 percent. Water availability was assessed by looking at water allocation decreased from the base of 160 percent of water right being available to 145 percent, 130 percent, and 100 percent. The study looked at results over a 10-year planning horizon. Additionally, Ho et al. considered a sensitivity analysis in regards to different levels of pasture consumption, which impacts the amount of feed the dairies would have to purchase to meet the cows’ nutritional requirements. The effects of the changes in water price and allocation on the two farms were assessed using discounted net cash budgets over a ten year period.

The results of this study (Ho et al., 2005) indicated that annual profits decline when irrigation water prices rise from the baseline on both farms. When prices were increased by 100 percent, the 'water-reliant' farm had profits reduced by $21,000 and the 'fodder-reliant' farm had profits reduced by $52,000. This was influenced by the level of pasture consumption and indicates that many farmers in this study area have the option to buffer the impacts of water price increase by improving pasture and feeding management. When water allocations were reduced from 160 percent to 100 percent of water right, the 'water-reliant' farm's operating income decreased by $22,000 and the 'fodder-reliant' farm fell by $35,000. In both scenarios, the 'water-reliant' farm experienced greater loss in terms of percentage reduction in operating profit.

Ho et al. (2005) concluded small increases in water price and small reductions in the water allocation will not have a substantial impact on the viability of efficient, well managed dairy farms. However, large increases in the price of water and/or large reductions in water allocations will have substantial impact on the profitability of dairy farms, particularly 'water-reliant' farms and less efficient farms.

Spatial Analysis

Spatial analyses are conducted in order to determine how location impacts a variable. This section reviews various methods that are used to understand spatial relationships within an industry.

Sambidi and Harrison (2006) examined the spatial relationships within the U.S. biotech industry, and determined what factors affect the location of biotech firms. They hypothesized that biotech firms will cluster across space in order to take advantage of agglomeration economies. A global Moran's I, which is used to determine the degree of spatial autocorrelation, was calculated to be 0.3058, which indicates a significant strong positive spatial relationship. This shows that counties with a high or low number of biotech firms are located near similar counties. The Local Indicators of Spatial Association (LISA) statistic, which measures the contribution of individual counties to the Global Moran's I statistic, showed several areas of positive and high autocorrelation across the U.S. One of the factors the authors were interested in was how agriculture production influenced location of biotech firms. They used a Multivariate Local Moran Statistic in order to determine the spatial relationship between farmland and the spatial lag of the dependent variable (number of biotech establishments), which was calculated to be -0.0316, which indicates a significant negative spatial relationship between the two variables. Since using a classic OLS will result in biased results due to the spatial relationships, they utilized a Bayesian spatial tobit model to capture the spatial organization of the industry. The pseudo R-Square value was 0.54, and the spatial lag coefficient was positive and significant. Therefore, the authors concluded that biotech firms tend to concentrate across regions in order to utilize positive externalities associated with agglomeration economics. Most of the variables used in the spatial tobit model had the anticipated signs and significantly differed from zero. Some of the variables considered were poverty, population, median household income, colleges, education, property tax and farm land. The authors conclude that biotech firms do experience clustering, and that the hypothesis of agglomeration economics is confirmed.

Barona, et al. (2010) examined the spatial relationships between deforestation and changes in pasture and soybean areas in the Brazilian Amazon. As the global demand for soybeans and related products has risen, soybean cultivation has increased significantly in Brazil. This expansion has created rapid land-use changes in recent decades. It has been shown that soybean cropland is primarily expanding into former pastureland and is not causing new deforestation. The majority of deforestation appears to be the result of pastureland expansion. The relationship between agricultural expansion and deforestation over the years 2000-2006 was initially examined using an OLS linear regression model. It showed a weak relationship until outliers were removed. Then the regression was repeated with cropland or pastureland alone as the independent variable. Changes in pastureland showed a stronger relationship with deforestation than cropland changes. When run together in a multiple regression model, both variables showed significance. A centroid analysis was then performed to show the spatial shifts in deforestation and agricultural land. It was determined that a northward shift of soybean acreage was accompanied by northward shift of both pasture and deforestation. Even though deforestation was primarily caused by pasture expansion, soybeans expanded into land previously used for pasture. The authors concluded that even though pastureland expansion was the proximate cause for deforestation, expansion of soybean cropland is likely a major underlying cause.

Airna, et al. (2011) also examined land use changes in the Brazilian Amazon. Their methods differed from Barona et al. in that they used a spatial regression model rather than a centroid analysis. The analysis was conducted at the municipo (county) level for the years 2002-2008. The study area was partitioned spatially into a time-dependent ‘forest frontier’ and ‘agricultural area’. Spatial weight matrices were calculated and used to create independent variables capturing soy expansion in distant municipalities as a function of nearness to the observations in the forest frontier. Using spatially weighted independent variables resulted in a spatial Durbin model (SDM). The SDM relies on a matrix linking points of impact to distal, independent variables. Their results also indicate that deforestation in the forest frontiers is strongly related to soybean expansion

Wright, Hudson, and Mutuc (2013) used a spatial analysis in order to understand spillovers in the adoption of irrigation technology. The physical location of users and the geographic relationship between current users and potential adopters influences the technology adoption process. Technology is more likely to diffuse to neighboring counties that share similar characteristics and are geographically close to one another if spatial spillovers are present. In order to determine the growth of the center pivot irrigation technology in the Texas High Plains, a spatial regression model was used. Independent variables used included saturated thickness of the Ogallala Aquifer, change in saturated thickness, distance between a county and an experiment station, amount of irrigated production in a county, and aridity level in a county. A simple OLS model was used for variables that do not show spatial variation, such as market average prices and interest rates. A distance spatial weights matrix was used in this model, which assumes that all counties in the study region should have some effect on each other, but the effect should decrease as distance increases. Spatial clustering was tested with a Moran's I statistic, which showed spatial autocorrelation in the first three of the six time cross sections. This reduction in spatial autocorrelation over time suggests that specific characteristics of a county influenced initial adoption and then as the technology diffused, spatial autocorrelation disappeared. This could be the result of having a small study area and/or an extreme outlier in a county.

An exploratory analysis of the dairy industry was conducted in this thesis. The impacts of the industry on the Texas High Plains were evaluated considering water usage and economic implications and, while also exploring the spatial distribution of the industry. With the dairy industry being an evolving presence in the Texas High Plains, there are few existing studies that examine the economic impact at the localized level. This study builds upon the study conducted by Guerrero, Amosson, and Jordan in 2012 that examined the dairy industry in the entire Southern Ogallala Region. The study presented in this thesis instead looks at more localized impacts of the dairies using other approaches rather than using IMPLAN, which is used at the broader regional level. Applications of these concepts in different settings were examined within this literature review.

CHAPTER III

DATA AND METHODS

Study Area

The Ogallala Aquifer stretches from South Dakota to Texas and underlies eight states (South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas). The Southern Ogallala Region, which includes the Texas High Plains, has experienced the greatest reduction in aquifer levels. This study focuses on the following counties in the Texas High Plains: Andrews, Armstrong, Bailey, Borden, Briscoe, Carson, Castro, Cochran, Crosby, Dallam, Dawson, Deaf Smith, Dickens, Donley, Floyd, Gaines, Garza, Glasscock, Gray, Hale, Hansford, Hartley, Hemphill, Hockley, Howard, Hutchinson, Lamb, Lipscomb, Lubbock, Lynn, Martin, Midland, Moore, Motley, Ochiltree, Oldham, Parmer, Potter, Randall, Roberts, Sherman, Swisher, Terry, Wheeler, and Yoakum (Figure 1). These counties were chosen because of their location over the aquifer as well as the increased dairy presence in this region.

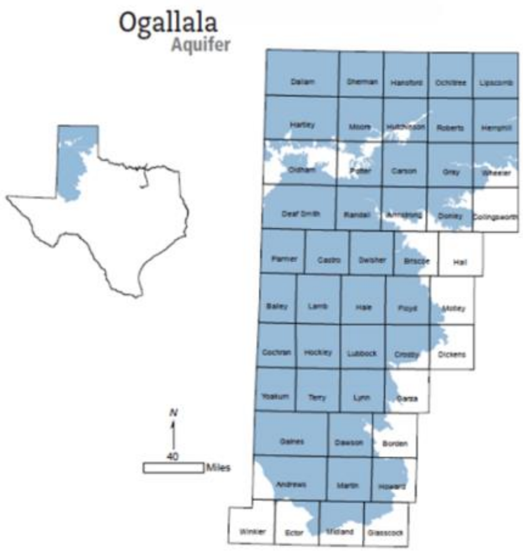

Figure 1. The Study Area over the Ogallala Aquifer.
Source: Partain, 2014

<u>Data Collection</u>

To determine the changes in crop composition in the study region, annual irrigated crop acreages were collected from the Farm Service Agency (FSA) for the years 2000-2015 (Farm Service Agency, 2018). The following irrigated crops were included in this analysis as they are the most prevalent crops grown in the study area: corn, sorghum, and wheat. Cotton is also a major irrigated crop in the region but was not included in this analysis as it is not heavily influenced by the dairy industry. Since dairies were expected to have a larger impact on forages rather than grains, acres of crops intended for forage purposes were separated out from acres of crops intended for grain. Forage included the FSA intended use codes of forage, hay, and silage. Only irrigated acreages were considered in an effort to detect any impacts these changes may have had on the aquifer.

Information on business composition in the Texas High Plains' economy was obtained from the United States Census Bureau (County Business Patterns, 2017).

Included in this dataset is number of establishments, annual payroll, first quarter payroll, and number of employees, as well as a break-down of the number of establishments by number of employees for each industry sector by the North American Industry Classification System (NAICS) code and by county. Data was compiled for the years 2000 and 2015. Payroll was adjusted for inflation by deflating 2015 values to 2000 values using the Employment Cost Index (ECI) values from the Bureau of Labor Statistics (Bureau of Labor Statistics, 2018). Population data was also obtained to examine what changes occurred over the study period (Census Bureau, 2017). Data were able to be obtained for the year 2000, but only estimates were obtained for the year 2015 due to the census only occurring every ten years.

Dairy cow inventory was collected by county through the federal Milk Marketing Order for the years 2000-2015 (Federal Milk Marketing Order 126, 2017). The dairy cow inventory was calculated by using the estimate of seventy pounds of milk production per day per cow (Jordan, 2017) in conjunction with the total milk production from each county. Even though this method does not capture dry cows or replacement heifers, it was still found to be more accurate than using National Agricultural Statistical Services (NASS) data, which had missing observations due to the survey method of collecting voluntary responses. Counties with less than three dairies did not report production due to discretionary issues and were not included in this analysis.

General Approach

To examine the impact of the dairies in the Texas High Plains, the study used various descriptive analyses and the process can be summarized in several steps. First, to calculate the amount of water the dairies were using over the course of the study period, both direct and indirect uses had to be considered. For direct usage, which includes drinking water as well as water needed for facility cleaning and maintenance, industry experts estimate that each dairy cow requires 65 gallons of water per day (Amosson, Marek, and Hillyer, 2017). Indirect usage, which is defined as the amount of water used to irrigate the crops used for feed, was based on the dairy cow ration (Jordan, 2011). The total required amount of each component of the ration was calculated based on the ration and annual cow inventory. The number of acres needed to produce this amount and the associated water were computed based on the estimated irrigation requirements and crop yields per acre from the Texas A&M AgriLife Extension Crop Enterprise Budgets (Table 1) (Amosson et al., 2017). The total production demanded by dairies was divided by the yield per unit of water applied to obtain an estimate of the total indirect water requirement of dairies. Then, total water usage for the year could be determined by combining direct and indirect water usage.

Table 1. Water Requirements and Yields for Selected Irrigated Crops in the Study Region.

Crop	Irrigated Water Applied (ac-ft)	Yield (Tons)	Tons/ac-ft
Corn Grain	1.83	6.3	3.4
Corn Silage	1.67	27.0	16.2
Sorghum Grain	0.83	3.0	3.6
Sorghum Silage	1.08	21.0	19.4
Wheat Grain	0.83	1.5	1.8

Before applying any statistical tests, the data were tested for normality using the Shapiro Wilk's test for all the variables of interest. The test results suggest that all variables in both the crop dataset and the county business patterns dataset were nonnormal. Log transforming the data only corrected a portion of the variables. Therefore, the data had to be analyzed non-parametrically.

The Wilcoxon test, a non-parametric t-test option within SAS's PROC NPAR1WAY, was used to determine if there was a significant change in number of acres of crops grown from the beginning of the expansion period in 2000 to 2015. The Wilcoxon test was also used to determine if there were any differences in employment, annual payroll, or number of establishments for each NAICS industry. This test was then repeated using only data from counties that reported dairy inventory numbers.

Some forage composition and business composition changes in the study area were too small to be captured statistically. Therefore, changes between years in both the FSA and the CBP datasets were then further analyzed descriptively. Industries of interest were examined at the six digit NAICS code level, the most descriptive classification level. The number of establishments and employees were compared between 2000 and 2015 to examine the changes that occurred.

A spatial autocorrelation analysis on dairy data was also performed using GeoDa, a spatial data analysis software (Anselin, 2006). More specifically, Moran's I statistic, an indicator of spatial autocorrelation, was computed and visualized by means of a Moran's I scatterplot. This gave more information on the spatial distribution of the dairies and the implications this could have on the study region.

CHAPTER IV

RESULTS

At the beginning of the study period (2000), dairy cow inventory was only 12,066 head for the entire region and the total water usage was 36,830 ac-ft (Table 2). As the number of cows increased, the demand for feed and water usage increased as well. In 2015, inventory was 262,622 head and total water usage (direct and indirect) reached 801,623 ac-ft, which is a 2077 percent increase. However, total irrigated acreage in the Texas High Plains over the course of the study period did not change significantly and actually shows a decrease of 17.8 percent from 2000 to 2015 (Table 3). This indicates that while there was an increased irrigation requirement from the demand of feed by the dairies, this did not increase the overall irrigation in the region and instead represents a trade-off. Irrigated acreages were allocated differently throughout the study period, with more acres being used for silage and fewer acres for grain as indicated by the percentage increase in silage from 2.13 percent in 2000 to 6.86 percent in 2015 (Table 3).

Table 2. Dairy Inventory and Water Use for the Study Region.

	2000	2005	2010	2015
Total Inventory (head)	12,066	79,222	192,790	262,622
Direct (ac-ft)	879	5,768	14,037	19,121
Indirect(ac-ft)	35,952	236,048	574,432	782,502
Total Water Use (ac-ft)	36,830	241,816	588,469	801,623

Table 3. Total Irrigated Acres and Irrigated Silage Acreage (%) in the Study Region.

	2000	2005	2010	2015
Total Irrigated Acres	5,042,311	4,317,744	4,397,120	4,143,415
Irrigated Silage (% of Total Irrigated Acres)	2.13%	3.37%	4.56%	6.86%

Dairy cow inventory is expected to continue increasing over the next few decades. The livestock technical memorandum for Senate Bill 5 (Amosson, Marek, and Hillyer, 2017) projects dairy inventory will increase by 2 percent annually for every county from 2017 to 2030 and then increase by 1 percent annually for every county from 2030 to 2070. Using these growth rates, inventory numbers were predicted for the next 10, 20, and 30 years in the Texas High Plains. Future water use by the dairy industry was estimated given these numbers (Table 4). Water use in 2045 represents a 91 percent increase from the 2015 levels. From these projections, it can be determined that even though the industry will still be growing, it will be growing at a slower rate than during the study period (2000-2015).

Table 4. Projected Dairy Inventory and Water Use for the Study Region.

	2025	2035	2045
Projected Inventory (head)	391,114	453,848	501,330
Direct (ac-ft)	28,477	33,044	36,502
Indirect (ac-ft)	1,165,353	1,352,274	1,493,750
Total Water Use (ac-ft)	1,193,830	1,385,318	1,530,252

Plotting irrigated crop acres for all counties in the study region shows little change from the beginning to the end of the study period with some variability between years with the exception of wheat acreage (Figure 2). Therefore the Wilcoxon t-test showed the only crop to have a significant difference between the year 2000 and the year 2015 was wheat (p-value: 0.0337), which showed a decrease over time. This decrease in wheat acreage is explained by historically low wheat prices in recent years.

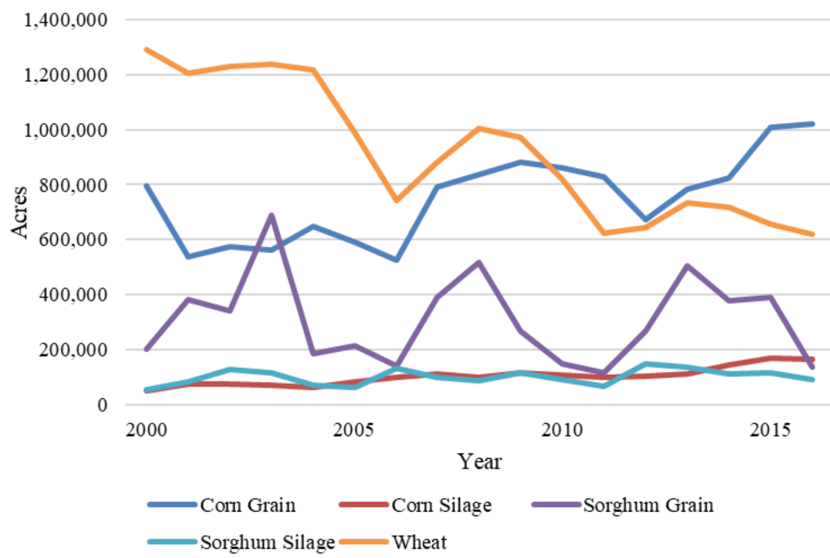

Figure 2. Irrigated Acres for Selected Crops in the Study Region, 2000-2015.

The Wilcoxon Test was repeated using only counties that reported dairies, which includes Bailey, Castro, Dallam, Deaf Smith, Hale, Hartley, Lamb, Moore, and Parmer Counties. All of the crops showed a significant increase in acreage (Table 5) with the exception of wheat forage. However, the decrease in wheat forage was not as extreme as was reported across the entire study period for wheat grain. This is likely due to the increasing demand for forages for the dairies in these counties. The acreages of forage crops for the nine dairy producing counties were plotted in Figure 3 along with dairy inventory numbers. Corn silage, which many dairies rely on heavily, follows the rise in dairy inventory most closely. Texas experienced a drought from 2010 to 2011 which impacted agricultural production in the region. This explains the dip in acreage for all three forage crops during this period. The next year shows that corn silage remains low while sorghum silage and wheat forage acres increase, demonstrating an inverse relationship between the substitutes. Corn silage requires more water per ton than silage, which impacts producer planning decisions during periods of drought (Table 1). Additionally, sorghum silage shows a higher number of acres in 2015 compared to the beginning of the study period, which may indicate more limiting pumping capacity as the aquifer continues to deplete.

Table 5. Wilcoxon Test Results for Irrigated Crops in Dairy Producing Counties.

Crop	2000 Total	2015 Total	p-value
Corn Grain	589,143	608,947	0.0203
Corn Silage	38,465	152,037	0.0025
Sorghum Grain	97,773	176,924	0.0491
Sorghum Silage	31,708	84,334	0.0243
Wheat Forage	22,970	22,080	0.9307

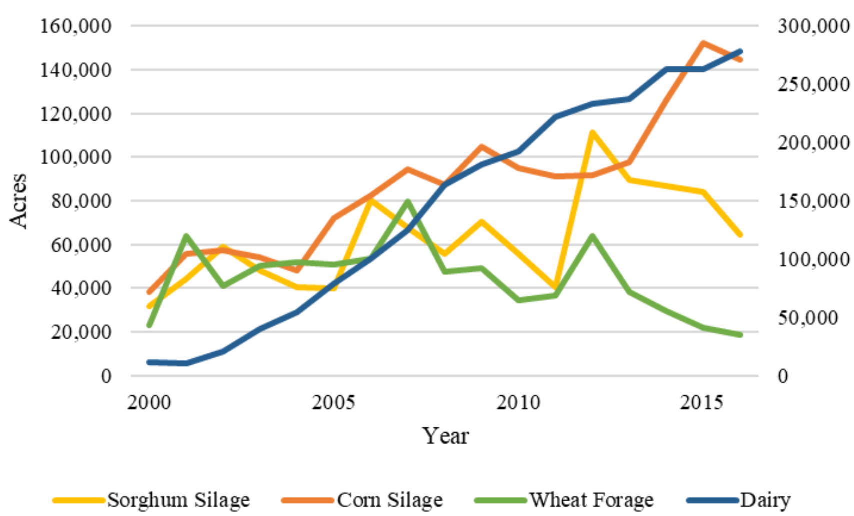

Figure 3. Irrigated Silage Acres and Dairy Inventory in Dairy Producing Counties.

The Wilcoxon t-test was then performed on the County Business Patterns data. Results indicated that there was no change for most variables. The exceptions were annual payroll in the transportation and warehousing sector and number of establishments in the miscellaneous industries category (Table 6). Both sectors showed a significant difference between the year 2000 and 2015 at the 5% significance level. Additionally, employment for transportation and warehousing had a p-value of 0.06, which indicates a decreasing trend in employment, even if the difference was not statistically significant. When the test was rerun using only the nine counties with dairies, the results showed no significant changes in all the variables. This indicates the test was not sensitive enough to detect any changes. It is important to note that this test was performed on NAICS sectors at the two-digit level only.

Table 6. Wilcoxon Test Results for County Business Patterns Dataset for the Study Region.

Industry and Variable	2000 Mean	2015 Mean	p-value
Transportation and Warehousing - Annual Payroll	37.09	49.05	0.0274
Miscellaneous- Number of Establishments	32.49	19.50	0.0056
Transportation and Warehousing - Employment	37.97	48.14	0.0606

Since very few changes were captured with the Wilcoxon test, NAICS sectors of note in each of the nine producing dairy counties were further examined at the six-digit level, which is the most descriptive level. Any sector that experienced a large change in number of establishments or number of employees was examined more closely to determine where these changes occurred. Only changes in relevant six-digit classifications were presented in the following tables. Total changes at the two-digit level are provided in Appendix A (Tables A1-A9).

In Bailey County, the only industry that showed significant change was the manufacturing industry, with an overall increase in 130 employees and four establishments (Table A1). The increase appears to be primarily due to the appearance of pallet manufacturing, with two additional establishments and an average of 50 employees and farm machinery manufacturing with one additional establishment and 15 employees (Table 7). The farm machinery manufacturing sector produces goods that can be utilized on dairy farms or in the production of feed for the dairies.

Table 7. Establishment and Employment Changes in Bailey County.

NIACS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
311211	311211	Flour Milling	1	1	175	175
311611	311611	Animal Slaughter	0	1	0	2
321920	321920	Pallet Manufacturing	0	2	0	50
333111	333111	Farm Machinery	0	1	0	15

Castro County had changes in three industries to note: the manufacturing industry, wholesale trade industry, and health care and social assistance industry (Table A2). The manufacturing industry’s decrease in employment is primarily due to the closure of a Cargill corn milling plant in 2006, which decreased employment for the industry by 175 employees (Table 8). It is likely many of these workers relocated, negatively impacting other businesses in the county. The two new animal feed establishments help to supply both the fed beef and dairy industries. The wholesale trade industry decreased by 134 employees (Table A2) due to several smaller businesses closing, such as a flower nursery wholesaler, several farm and garden machinery wholesalers, and two petroleum bulk station wholesalers. However, several additional farm supply wholesalers are reported in 2015 that were not present in 2000. The increase in veterinary services could very well be linked to an increased dairy presence.

Table 8. Establishment and Employment Changes in Castro County.

NIACS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
311221	311221	Wet Corn Milling	1	0	175	0
311119	311119	Animal Feed	0	2	0	9
421820	423820	Farm and Garden Machinery Wholesalers	8	4	58	26
422510	424510	Grain and Bean Wholesalers	6	1	76	30
422520	424520	Livestock Wholesalers	1	1	75	2
422910	424910	Farm Supplies Wholesalers	2	7	32	68
541940	541940	Veterinary Services	0	1	0	15

Dallam County is where the Hilmar Cheese plant is located, but the workers employed by Hilmar were not reported in the CBP dataset likely due to discretionary issues. The plant initially employed 120 people when it opened in 2007, then added another 130 by the end of their second phase of expansion. By 2015, the plant employed over 400 workers. The construction industry had an increase of 125 employees and seven establishments (Table A3). Many smaller changes occurred in this industry, such as the establishment of additional electrical contractors and two site preparation contractors (Table 9). These changes reflect the growing population's need for more houses and businesses. Workers for the dairies and Hilmar contributed to this population increase, and therefore were the primary factor that increased demand for the construction. Specific population changes by county are provided in Appendix A (Table A10).

Table 9. Establishment and Employment Changes in Dallam County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
235310	238210	Electrical Contractors	3	6	11	58
-	238910	Site Preparation Contractors	0	2	0	72

Deaf Smith County experienced expansion in several industries. The manufacturing industry experienced a 386 employee increase across many classifications (Table A4). Animal slaughter had a single business increase employment to 750 workers in 2015 (Table 10). Dairies send cows to slaughter for a variety of reasons, including poor milking performance, age, or health. The cull rate for dairies in this region is about 36 percent (Jordan, 2018). In 2015 this resulted in more than approximately 11,000 cull cows sent to slaughter in Deaf Smith County and 94,544 cull cows for the entire Texas High Plains Region. Since the fed beef industry is well established in this county, the increase in number of cattle slaughtered and the resulting plant expansion is primarily due to the increased dairy presence. Other changes were smaller and included the establishment of a 75 employee food product machinery manufacturer, which could potentially be supplying equipment to the various dairy processing plants in the Texas High Plains, two additional farm machinery and equipment manufacturers, and the closure of a 175 employee beet sugar manufacturing plant. Transportation and warehousing had 131 additional employees in 2015 compared to 2000 (Table A4). The increase is due to an increase in the size of local general and long distance specialized freight trucking businesses. Livestock, feed, bulk liquid, and refrigerated products all fall under the specialized freight classification, which indicates the dairy industry is a large contributor to these increases.

Table 10. Establishment and Employment Changes in Deaf Smith County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
311611	311611	Animal Slaughter	2	1	182	750
311313	311313	Beet Sugar Manufacturing	1	0	175	0
333111	333111	Farm Machinery and Equipment Manufacturing	1	3	30	34
333294	333241	Food Product Machinery Manufacturing	0	1	0	75
484110	484110	General Freight- Local	6	9	38	100
484230	484230	Specialized Freight- Long Distance	4	7	49	55

Hale County experienced changes in several industries over the course of the study period (Table 11). The construction industry increased by 113 employees due to small changes in size for most business classifications (Table A5). The manufacturing industry lost 2,109 employees primarily due to the closure of a Cargill animal processing plant that employed approximately 2000 workers in 2013. Smaller herd sizes due to drought was cited as the main reason for the closure of the plant (Hawkes, 2013). Consequently, the one establishment in the meat processors classification dropped an employment bracket down to 15 employees and the rendering establishment present in 2000 was not reported in 2015.

Table 11. Establishment and Employment Changes in Hale County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
311611	311611	Animal Slaughter	1	0	2000	0
311612	311612	Meat Processors	1	1	30	15
311613	311613	Rendering	1	0	30	0
333111	333111	Farm Machinery and Equipment Manufacturing	3	2	182	32
421820	423820	Farm and Garden Machinery Wholesalers	9	14	124	336
422510	424510	Grain and Field Bean Wholesalers	12	6	72	56
422520	424520	Livestock Wholesalers	1	1	30	2
422910	424910	Farm Supplies Wholesalers	7	15	73	158
484121	484121	General Freight- Long Distance	7	10	362	198
493110	493110	General Warehouse and Storage	0	3	0	795

Wholesale trade in Hale County experienced an increase of 162 employees (Table A5). The farm and garden machinery wholesaling classification had a large increase in both number of establishments and employment size, including the establishment of a single business that employees 175 workers. Farm supply wholesalers also increased but grain and field bean and livestock wholesalers decreased (Table 11).

The transportation and warehousing industry increased by 900 employees primarily due to the establishment of a single warehouse that employed 750 workers in 2015 that was not present in 2000 (Table 11). In addition, long distance general freight trucking decreased in employment size from 362 to 198.

Hartley County experienced smaller changes overall with only one industry, construction, having a change larger than 100 employees (Table A6). Residential remodelers and commercial and institutional building construction had new businesses establish (Table 12). Population increases required more housing as well as commercial buildings for businesses to support the increased demand. Workers from the dairies as well as for Hilmar, which is in the neighboring county, contributed to the population increase. Even though transportation and warehousing had a smaller change in this county, there was enough of a change in this industry that can be related to the dairy industry. The 87 employee change is due almost solely to the increase in general and specialized freight trucking for both local and long distance. Thus, the increase in specialized freight is primarily due to dairies in the county. Even though no one business was larger than 49 employees, there were 9 additional business in the transportation sector established during the study period.

Table 12. Establishment and Employment Changes in Hartley County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
-	236118	Residential Remodelers	0	2	0	4
233320	236220	Commercial and Institutional Building	0	2	0	32
484121	484121	General Freight- Long Distance	0	3	0	34
484220	484220	Specialized Freight- Local	1	5	2	36
484230	484230	Specialized Freight- Long Distance	0	2	0	9

Lamb County had only decreases in employment and establishments in the industries that were examined (Table 13). The manufacturing sector decreased by 580 employees primarily due to the closure of a denim textile plant (Table A7). This denim plant was then purchased by Select Milk Producers, Inc., which plans to turn the facility into a state of the art milk processing facility. The conversion will cost $250 million and around 150 workers will be hired when it is opened in late 2018. In addition, construction workers will be required to complete the project. The facility will be able to process four billion pounds of milk per day and will produce dairy products such as cheese and ice cream (Freeman, 2015). Two power-driven hand tool manufacturing plants also closed resulting in a loss of 77 employees.

Table 13. Establishment and Employment Changes in Lamb County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
313210	313210	Broad Woven Textile Mill	1	1	750	7
333991	333991	Power Driven Hand Tool Manufacturing	2	0	77	0

The changes in Moore County were primarily in the construction and manufacturing industries (Table 14). The increase in electrical contractors and plumbing, heating and air conditioning contractors is again likely due to population increase, which could be related to the growth of the dairy industry. However, since the oil and gas pipeline construction classification and petroleum refinery classification also experienced growth during this time, this could be a confounding factor in this explanation. The largest contributor to the employment increase was the expansion of a cattle processing facility that grew from 2000 employees in 2000 to 3750 employees in 2015. The fed beef industry did not experience much growth during this time, so the increases are likely due to dairy cull cows, and also additional processing due to the closure of the slaughter plant in Plainview, TX. When considered in conjunction with the large increase in the size of grain and field bean wholesalers and farms supply wholesalers, these changes indicate that agriculture, and the dairy industry specifically, is growing in the county and is likely contributing to population growth.

Table 14. Establishment and Employment Changes in Moore County.

NAICS 2000	NAICS 2015	Description	2000 Est	2015 Est	2000 Emp	2015 Emp
-	237120	Oil and Gas Pipeline Construction	0	3	0	265
235310	238210	Electrical Contractors	2	2	9	45
235110	238220	Plumbing, Heating and A/C	8	7	31	65
311611	311611	Animal Slaughter	2	2	2002	3780
324110	324110	Petroleum Refinery	1	1	375	750
422510	424510	Grain and Field Bean Wholesalers	10	6	89	216
422910	424910	Farm Supplies Wholesalers	2	7	17	47

Parmer County did not experience the same changes as the other dairy producing counties. No industry had more than a 100 employee change and therefore this county was not analyzed further for this portion of the study.

Since the transportation industry was a major factor of interest in the dairy producing counties of Deaf Smith, Hale, and Hartley, an analysis was conducted to determine how much of an impact the dairy industry had on the transportation industry. The number of truckloads needed to haul the milk produced in the study area annually was calculated given the inventory and the production rate of 70 pounds of milk per day per cow (Jordan, 2017). The approximate number of truckloads needed to haul milk on an annual basis was calculated on the basis of approximately 7,500 gallons of milk per tanker (Extension, 2007). Using this method, it was estimated that 4,780 truckloads were needed to transport milk in the year 2000. This number increased to 104,240 truckloads of milk in 2015. Dairies close to Hilmar or any of the other processing plants in the region require local trucking from the dairy to the plant. For dairies further away, or for milk exported to other regions or states, long distance trucking is required. Through the calculation of transportation demand at the dairy level, any leakages from trucks traveling across county lines were still captured. Leakages occur when capital leaves a region's economy rather than remaining local. This could explain why several dairy producing counties did not report increases in the transportation sector, as transportation increases could be occurring in neighboring counties.

GeoDa was used in order to examine the spatial distribution of the dairy industry. In 2000, only a few counties reported dairies and all were close to the New Mexico border where Southwest Cheese would thereafter be established in 2005. (Figure 4). In 2015, dairies expanded to the north, closer to where Hilmar Cheese opened in 2006 (Figure 5). Furthermore, dairies tend to be concentrated on the western side of the Texas High Plains. This is where the majority of irrigated crop production occurs due to a greater number of irrigation wells. Therefore, the distribution of the dairies seems to indicate that location decisions are influenced by proximity to feed production and access to markets to sell their products.

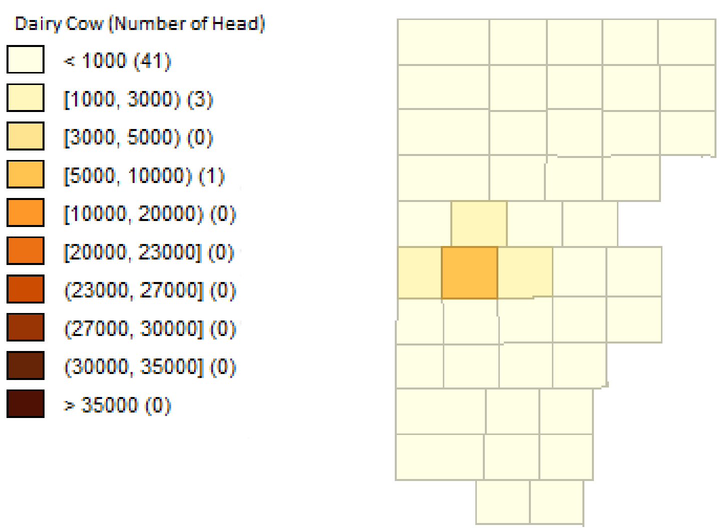

Figure 4. Spatial Distribution of Dairy Inventory by County in the Study Region, 2000.

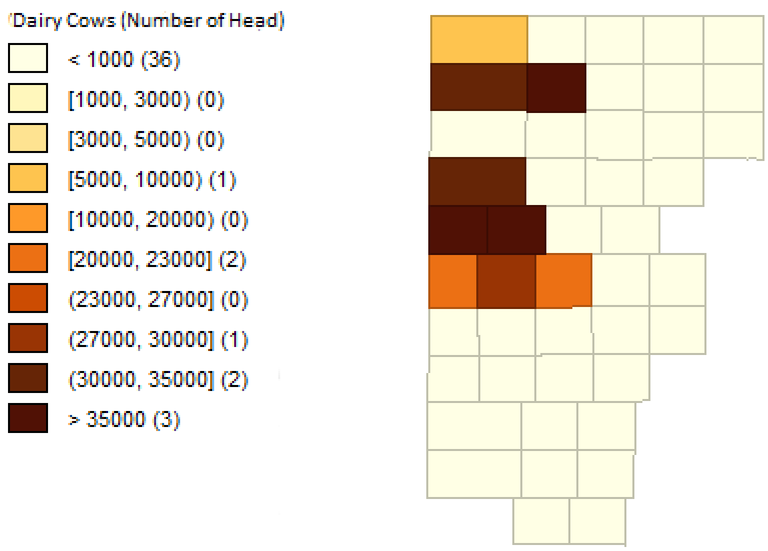

Figure 5. Spatial Distribution of Dairy Inventory by County in the Study Region, 2015.

The Moran's I statistic, which compares the value of a variable of interest at any one location with the value at all other locations, indicated that dairy inventory had a spatial dependence for both the year 2000 (Figure 6) and 2015 (Figure 7). A positive Moran's I indicates a spatial dependence, and the closer to 1 this value is, the higher the spatial dependency. The Moran's I for dairy inventory in 2000 was 0.2024 while in 2015 the Moran's I for dairy inventory was 0.4204. This indicates that spatial autocorrelation had a positive increase over the study period. The statistic was significant for both years at the 5% significance level.

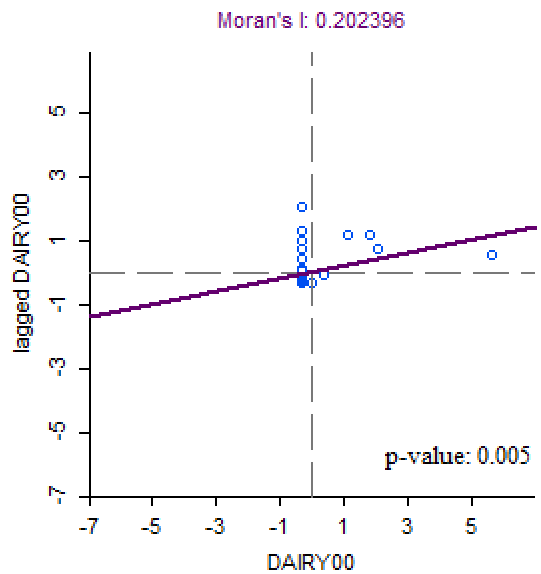

Figure 6. Moran's I Scatterplot for Dairy Inventory Distribution, 2000.

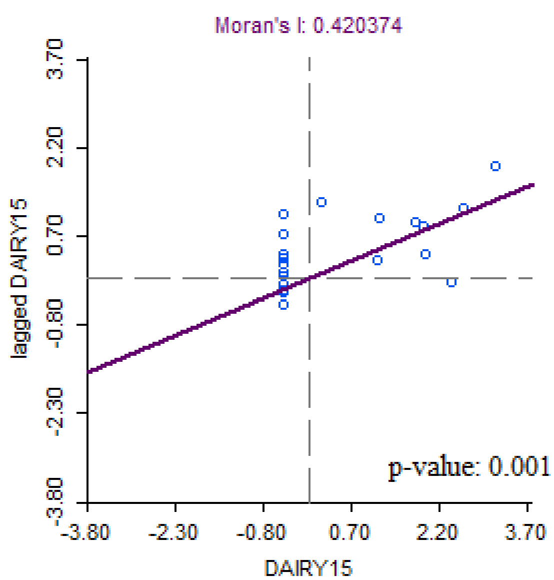

Figure 7. Moran's I Scatterplot for Dairy Inventory Distribution, 2015.

The LISA cluster maps for 2000 (Figure 8) and 2015 (Figure 9) indicate where the spatial autocorrelation occurs, with bright red color for a county with high dairy numbers near other counties with high dairy numbers. This occurred in Castro and Lamb Counties in 2000 and in Dallam, Deaf Smith, Parmer, Castro, Bailey and Lamb Counties in 2015 The bright blue color represents counties with low dairy numbers surrounded by counties with low dairy numbers. This occurred in Armstrong, Terry, and Martin Counties in 2015. The muted blue color indicates counties with low dairy numbers which were located next to counties with high dairy numbers. This happened in Parmer, Cochran, Hockley and Lubbock Counties in 2000 and in Oldham County in 2015.

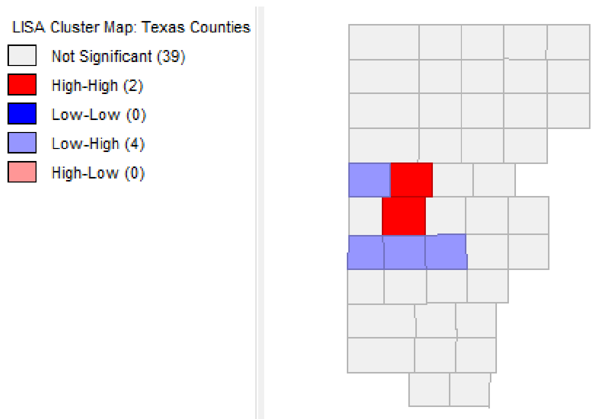

Figure 8. LISA Cluster Map for the Dairy Industry, 2000.

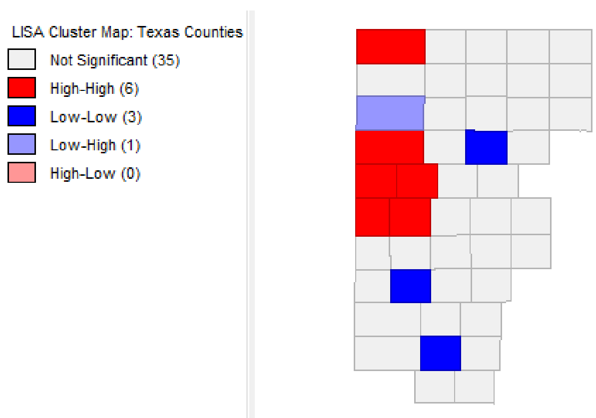

Figure 9. LISA Cluster Map for the Dairy Industry, 2015.

The LISA significance maps for the years 2000 (Figure 10) and 2015 (Figure 11) indicate the significance of these spatial relationships shown in the cluster map by using associated p-values. The darkest green represents a significance level of 0.001 while the lightest green represents a significance level of 0.05. In 2000, the counties with the highest significance for spatial autocorrelation are Lamb and Hockley Counties. The clustering behavior of the dairies strengthens with more counties showing significance in 2015. Parmer and Castro Counties become the most spatially significant for high number of dairies and Armstrong, Terry, and Martin Counties have the highest significance for low number of dairies.

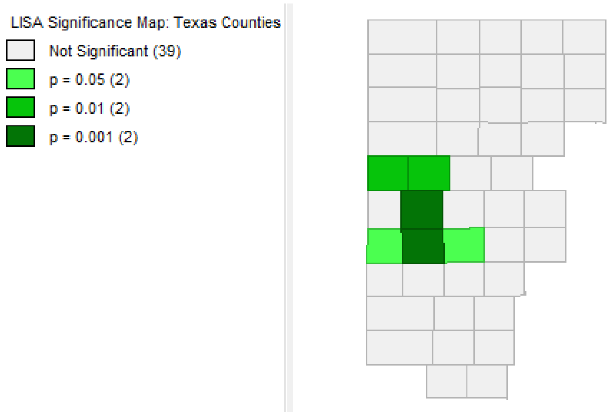

Figure 10. LISA Significance Map for the Dairy Industry, 2000.

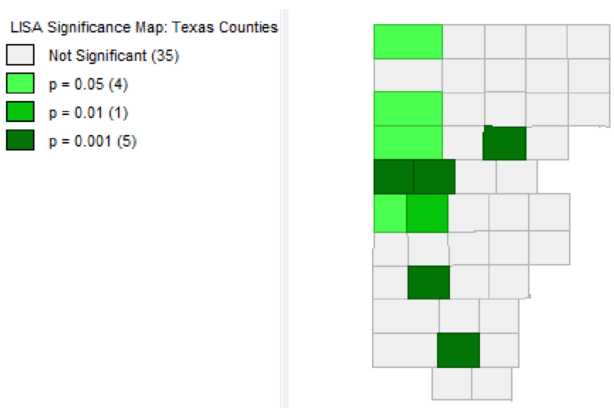

Figure 11. LISA Significance Map for the Dairy Industry, 2015.

CHAPTER V

SUMMARY AND CONCLUSION

This study considered how the dairy industry was impacting crop composition and therefore water usage, as well as localized business patterns in the Texas High Plains. By collecting data on crop acreages in the region, changes over time could be analyzed. Water use changes were estimated using irrigation levels, given the requirements of the dairies in the region. Finally, business changes were examined at the localized level using County Business Patterns data. This analysis revealed more acres were devoted to silage production instead of grain crops as a result of the expansion of the dairy industry, even though total irrigated acres decreased slightly during the study period. Several major employment changes occurred as a direct result of the dairy industry, such as increased animal slaughter plant size and establishment of dairy processing plants as well as increased transportation of livestock and milk, and indirectly through ripple effects in the economy.

Dairy cow inventory is expected to continue increasing over the next few decades. Complementary businesses like Hilmar continue to undergo renovation and expansion, and new plants such as the Select Milk Producers, Inc. are still establishing in the Texas

High Plains. The localized benefits from increased employment, income, and the number of supporting business establishments can be expected to continue to increase as well.

Even though the water use associated with dairies has increased over the past decade, the change in water usage is minimal when compared to total water used for irrigation for the entire Texas High Plains. The increase in water use was primarily due to the increased demand for silage. Even though irrigated acres of silage increased, total irrigated acres in the Texas High Plains decreased slightly during the study period. Therefore, irrigated acreage was allocated differently because of the dairies, with silage production displacing other irrigated crops. In addition, silage generally uses less water because it is harvested sooner than crops produced for grain. Silage production generates a higher value for producers than grain production for the water pumped when considering the prices that are received for those commodities. The industry generates economic activity in the area through increased employment and new establishments in related sectors like transportation. As the Ogallala Aquifer faces declining saturated thickness levels, concern over water conservation will continue to grow. These results will aid policy makers in determining the best strategy for conserving water while keeping the regional economy viable.

The limitations of only having non-normally distributed data to analyze prevented further analysis such as a regression or spatial regression analysis. One of the underlying assumptions of a linear regression analysis is that the variables are normally distributed. When the models were run with the intention of ignoring this violation to explore what results were generated, dairy inventory numbers did not show up as a significant explanatory variable for changes in any of the variables of interest (crop acreages, employment, number of establishments, and annual payroll for each industry), with very few exceptions. In most instances, the coefficients generated were incredibly small, and were often negative. This indicates that this statistical test was not appropriate for the dataset collected. This is likely due to the small sample sizes, since only nine counties reported dairies.

There are many topics of interest that were not covered in this study. Examining the factors that influence the location decision of dairies could be useful to predict where the dairies will establish in the future. Such factors could include land value, proximity to value-added businesses like the cheese processing plants, household income levels, and other population demographics. This will help determine where dairies will choose to locate in the future and therefore, where the benefits to localized economies will be strongest. Another approach to this topic would be to determine the impact of the cheese processing plants specifically by separating out the cow inventory by breed. Jersey cows are preferred for cheese production due to the high butter fat concentrations in their milk (Hilmar Cheese Plant, 2017). Therefore, a spatial analysis might reveal how proximity to the cheese processing facilities impacts the distribution of dairy cows by breed.

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APPENDIX A

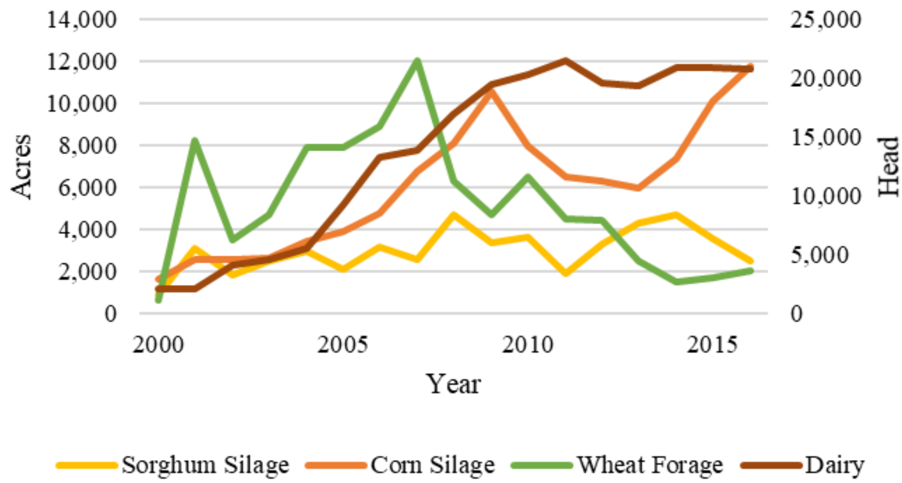

Figure A 1. Bailey County Irrigated Forage Acres and Dairy Inventory.

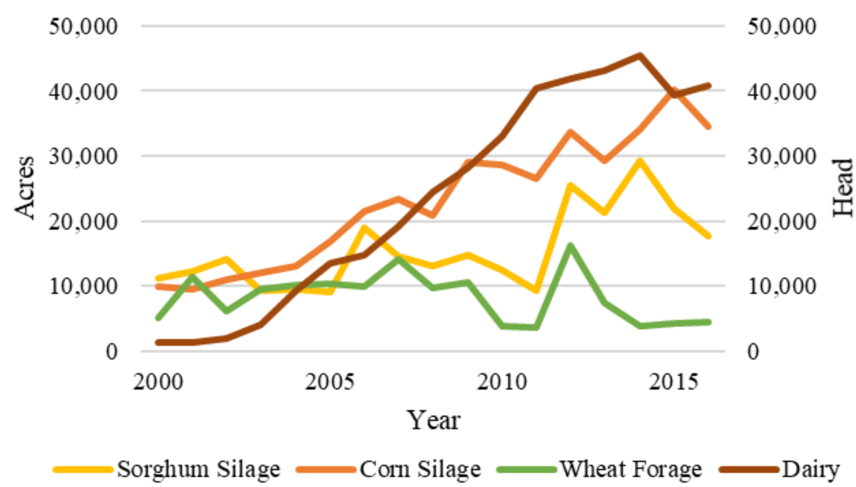

Figure A 2. Castro County Irrigated Forage Acres and Dairy Inventory.

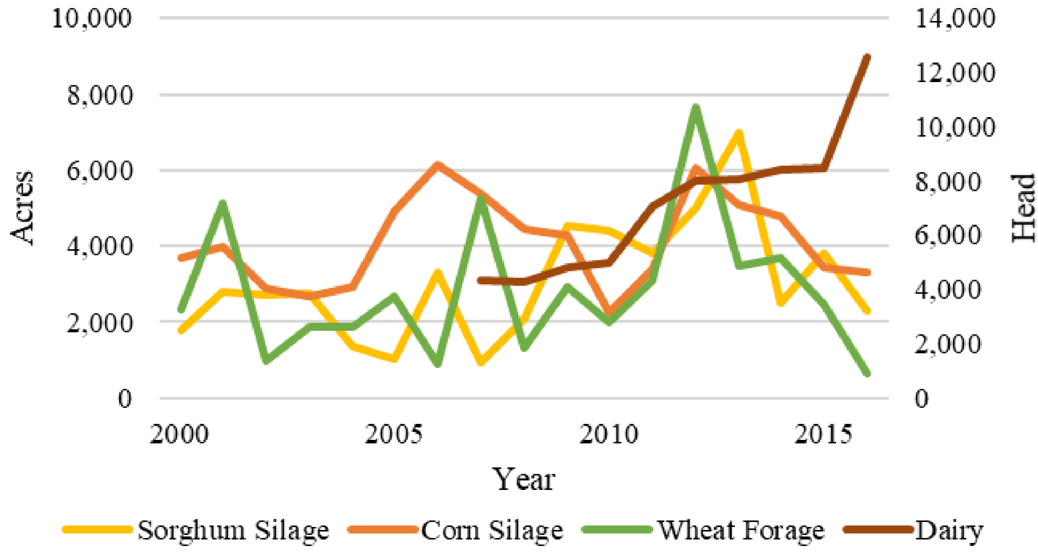

Figure A 3. Dallam County Irrigated Forage Acres and Dairy Inventory.

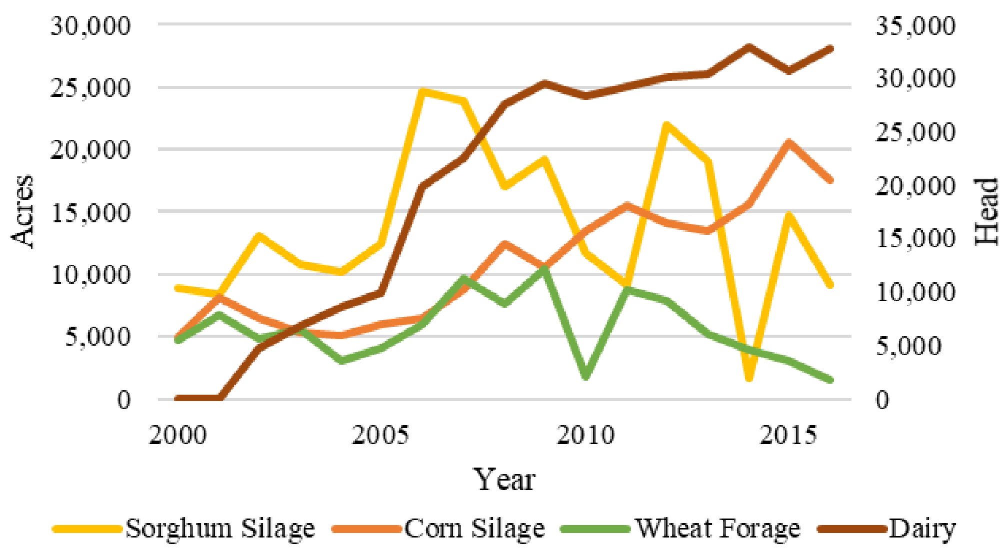

Figure A 4. Deaf Smith County Irrigated Forage Acres and Dairy Inventory.

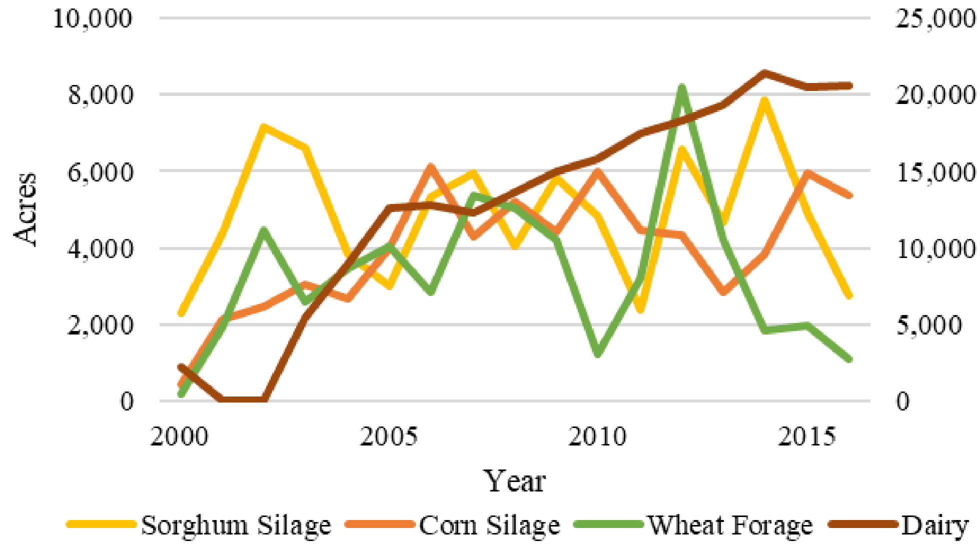

Figure A 5. Hale County Irrigated Forage Acres and Dairy Inventory.

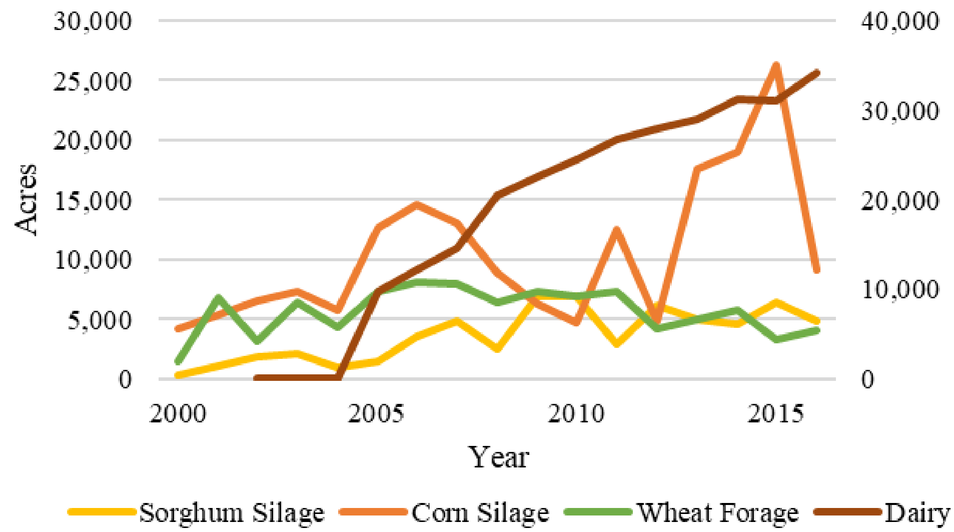

Figure A 6. Hartley County Irrigated Forage Acres and Dairy Inventory.

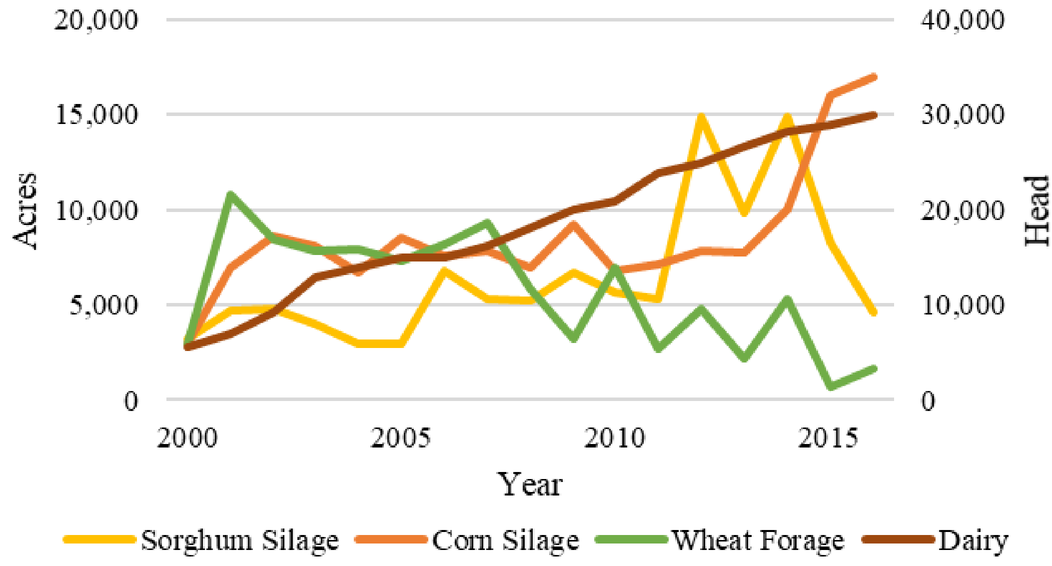

Figure A 7. Lamb County Irrigated Forage Acres and Dairy Inventory.

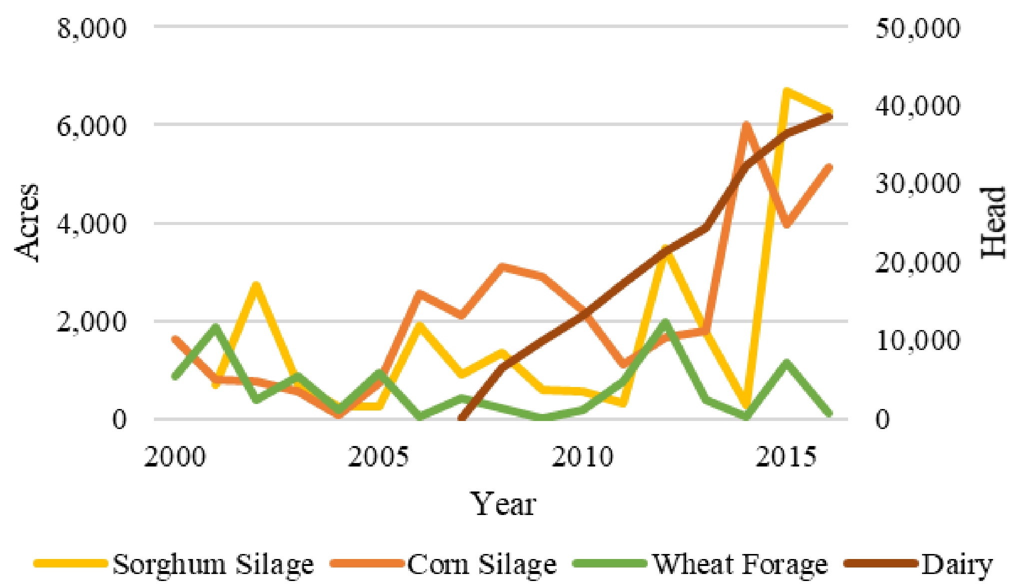

Figure A 8. Moore County Irrigated Forage Acres and Dairy Inventory.

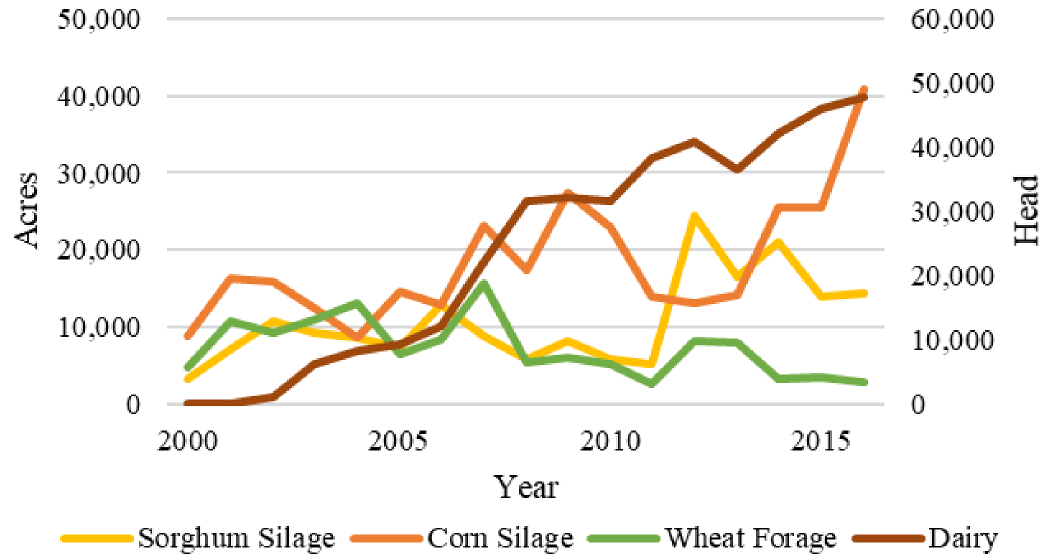

Figure A 9. Parmer County Irrigated Forage Acres and Dairy Inventory.

Table A 1. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Bailey County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	-40	-3
21	Mining	-	-
22	Utilities	0	0
23	Construction	-47	-3
31	Manufacturing	130	4
42	Wholesale Trade	-27	0
44	Retail Trade	-70	-14
48	Transportation and Warehousing	-13	-1
51	Information	0	0
52	Finance and Insurance	-1	3
53	Real Estate Rental and Leasing	10	1
54	Professional, Scientific, and Technical Services	-15	-3
55	Management of Companies and Enterprises	10	2
56	Administrative and Support, and Waste Management and Remediation Services	-2	-2
61	Educational Services	-	-
62	Health Care and Social Assistance	28	0
71	Arts, Entertainment, and Recreation	0	1
72	Accommodation and Food Services	4	0
81	Other Services	-36	-7

Table A 2. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Castro County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	-6	-2
21	Mining	-	-
22	Utilities	0	0
23	Construction	-39	-8
31	Manufacturing	-110	-1
42	Wholesale Trade	-134	-6
44	Retail Trade	-66	-9
48	Transportation and Warehousing	1	4
51	Information	0	-3
52	Finance and Insurance	-49	-6
53	Real Estate Rental and Leasing	16	5
54	Professional, Scientific, and Technical Services	70	4
55	Management of Companies and Enterprises	-	-
56	Administrative and Support, and Waste Management and Remediation Services	0	-2
61	Educational Services	-	-
62	Health Care and Social Assistance	-110	-7
71	Arts, Entertainment, and Recreation	-10	-16
72	Accommodation and Food Services	-1	0
81	Other Services	-6	-4

Table A 3. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Dallam County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	22	1
21	Mining	-10	-1
22	Utilities	0	1
23	Construction	125	7
31	Manufacturing	5	0
42	Wholesale Trade	5	-4
44	Retail Trade	-46	-15
48	Transportation and Warehousing	0	0
51	Information	-49	-4
52	Finance and Insurance	-28	-1
53	Real Estate Rental and Leasing	6	-1
54	Professional, Scientific, and Technical Services	13	1
55	Management of Companies and Enterprises	10	1
56	Administrative and Support, and Waste Management and Remediation Services	-28	-3
61	Educational Services	0	0
62	Health Care and Social Assistance	-6	-1
71	Arts, Entertainment, and Recreation	-37	3
72	Accommodation and Food Services	8	1
81	Other Services	49	-1

Table A 4. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Deaf Smith County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	-9	-4
21	Mining	0	-1
22	Utilities	11	0
23	Construction	-32	-4
31	Manufacturing	386	-5
42	Wholesale Trade	35	-9
44	Retail Trade	240	-19
48	Transportation and Warehousing	131	6
51	Information	-54	-3
52	Finance and Insurance	39	2
53	Real Estate Rental and Leasing	16	0
54	Professional, Scientific, and Technical Services	99	4
55	Management of Companies and Enterprises	-	-
56	Administrative and Support, and Waste Management and Remediation Services	5	0
61	Educational Services	0	1
62	Health Care and Social Assistance	-2	-2
71	Arts, Entertainment, and Recreation	9	0
72	Accommodation and Food Services	108	1
81	Other Services	-56	-12

Table A 5. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Hale County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	41	-7
21	Mining	0	1
22	Utilities	44	2
23	Construction	113	-8
31	Manufacturing	-2109	-9
42	Wholesale Trade	162	-7
44	Retail Trade	-150	-38
48	Transportation and Warehousing	900	6
51	Information	-72	-3
52	Finance and Insurance	-90	-12
53	Real Estate Rental and Leasing	-15	-4
54	Professional, Scientific, and Technical Services	-4	3
55	Management of Companies and Enterprises	0	0
56	Administrative and Support, and Waste Management and Remediation Services	-182	-14
61	Educational Services	-375	1
62	Health Care and Social Assistance	-119	-2
71	Arts, Entertainment, and Recreation	11	0
72	Accommodation and Food Services	16	-9
81	Other Services	-26	-26

Table A 6. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Hartley County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	29	6
21	Mining	10	1
22	Utilities	0	-2
23	Construction	121	8
31	Manufacturing	-50	-2
42	Wholesale Trade	52	6
44	Retail Trade	92	-5
48	Transportation and Warehousing	87	9
51	Information	10	2
52	Finance and Insurance	29	3
53	Real Estate Rental and Leasing	6	-1
54	Professional, Scientific, and Technical Services	1	-1
55	Management of Companies and Enterprises	-	-
56	Administrative and Support, and Waste Management and Remediation Services	0	1
61	Educational Services	0	0
62	Health Care and Social Assistance	-23	2
71	Arts, Entertainment, and Recreation	-30	1
72	Accommodation and Food Services	28	4
81	Other Services	69	6

Table A 7. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Lamb County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	-40	-8
21	Mining	-	-
22	Utilities	-122	0
23	Construction	-19	-12
31	Manufacturing	-580	-6
42	Wholesale Trade	-49	-3
44	Retail Trade	-126	-22
48	Transportation and Warehousing	-5	8
51	Information	-40	-3
52	Finance and Insurance	-13	-3
53	Real Estate Rental and Leasing	0	-5
54	Professional, Scientific, and Technical Services	33	5
55	Management of Companies and Enterprises	-125	2
56	Administrative and Support, and Waste Management and Remediation Services	-1	-5
61	Educational Services	-	-
62	Health Care and Social Assistance	-2	9
71	Arts, Entertainment, and Recreation	-10	-2
72	Accommodation and Food Services	22	-8
81	Other Services	-23	-13

Table A 8. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Moore County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	14	4
21	Mining	-46	-3
22	Utilities	0	-1
23	Construction	372	1
31	Manufacturing	462	-10
42	Wholesale Trade	129	3
44	Retail Trade	118	-9
48	Transportation and Warehousing	0	7
51	Information	-23	-1
52	Finance and Insurance	8	14
53	Real Estate Rental and Leasing	-11	3
54	Professional, Scientific, and Technical Services	16	4
55	Management of Companies and Enterprises	10	2
56	Administrative and Support, and Waste Management and Remediation Services	-135	3
61	Educational Services	-3	2
62	Health Care and Social Assistance	14	9
71	Arts, Entertainment, and Recreation	-100	-3
72	Accommodation and Food Services	217	-1
81	Other Services	24	-15

Table A 9. Changes in Employment and Number of Establishments by Two-Digit NAICS Code in Parmer County.

NAICS	Description	Emp	Est
11	Agriculture Forestry, Fishing, and Hunting	4	-1
21	Mining	0	0
22	Utilities	0	0
23	Construction	18	5
31	Manufacturing	0	0
42	Wholesale Trade	41	-1
44	Retail Trade	-100	-14
48	Transportation and Warehousing	-9	7
51	Information	-3	1
52	Finance and Insurance	-13	3
53	Real Estate Rental and Leasing	-1	0
54	Professional, Scientific, and Technical Services	12	1
55	Management of Companies and Enterprises	10	1
56	Administrative and Support, and Waste Management and Remediation Services	-100	-1
61	Educational Services	0	0
62	Health Care and Social Assistance	20	-1
71	Arts, Entertainment, and Recreation	0	-1
72	Accommodation and Food Services	-46	-7
81	Other Services	95	-4

Table A 10. Population Changes for Study Area by County, 2000-2015.

	2000	2015
Andrews	13,004	17,760
Armstrong	2,148	1,876
Bailey	6,594	7,181
Borden	729	633
Briscoe	1,790	1,474
Carson	6,516	6,057
Castro	8,285	7,669
Cochran	3,730	2,882
Crosby	7,072	5,992
Dallam	6,222	7,056
Dawson	14,985	13,111
Deaf Smith	18,561	18,830
Dickens	2,762	2,184
Donley	3,828	3,405
Floyd	7,771	5,917
Gaines	14,467	20,478
Garza	4,872	6,442
Glasscock	1,406	1,314
Gray	22,744	22,725
Hale	36,602	34,263
Hansford	5,369	5,538
Hartley	5,537	5,747
Hemphill	3,351	4,129
Hockley	22,716	23,275
Howard	33,627	36,708
Hutchinson	23,857	21,511
Lamb	14,709	13,275
Lipscomb	3,057	3,487
Lubbock	242,628	303,137
Lynn	6,550	5,711
Martin	4,746	5,723
Midland	116,009	162,565
Moore	20,121	22,120
Motley	1,426	1,160
Ochiltree	9,006	10,306
Oldham	2,185	2,076
Parmer	10,016	9,776
Potter	113,546	120,832
Randall	104,312	132,501
Roberts	887	916
Sherman	3,186	3,068
Swisher	8,378	7,466
Terry	12,761	12,799
Wheeler	5,284	5,546
Yoakum	7,322	8,488