EVALUATING THE DAIRY INDUSTRY'S ECONOMIC CONTRIBUTION AND WATER UTILIZATION IN THE SOUTHERN OGALLALA AQUIFER REGION

By

Estefania Gutierrez

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Approved:

Dr. Bridget Guerrero — Date
Chairman, Thesis Committee

Dr. Lal Almas — Date
Member, Thesis Committee

Dr. Justin Benavidez — Date
Member, Thesis Committee

Dr. Juan M. Piñeiro — Date
Member, Thesis Committee

Dr. Juan Velez — Date
Member, Thesis Committee

Dr. Lance Kieth — Date
Department Head, Agricultural Sciences

Dr. Kevin Pond — Date
Dean, Paul Engler College of Agriculture and Natural Sciences

Dr. Angela Spaulding — Date
Dean, Graduate School

ABSTRACT

The dairy industry in the Southern Ogallala Aquifer Region has continued to grow in the past decades. As dairy cow inventory continues to expand in the region, so do complementary economic sectors. It is essential to understand the dairy industry's contribution to the regional economy as public concerns grow over the diminishing availability of water. Thus, this research focuses on the dairy industry's economic contribution in the region as well as the water impact (direct and indirect) on the Ogallala Aquifer. Cows use water both directly and indirectly. Direct water use is water used by cows for drinking and facility maintenance. Indirect water use refers to water used for crop production, which is fed to cattle.

This study analyzed the dairy industry's contribution to the regional economy for 120 counties that make up the Southern Ogallala Aquifer Region. IMpact analysis for PLANning (IMPLAN) was used to estimate the direct, indirect, and induced economic contribution of the dairy industry in terms of income, economic output, and employment in the region. Direct and indirect water usage were evaluated using an estimated inventory of dairy cows and a representative ration per cow unit for the Texas High Plains, which was assumed for the entire region. Inventory data were estimated from 2000 to 2020 to provide insight into the continued growth in the region.

Dairy cow inventory in the Southern Ogallala Aquifer region increased from 156,513 dairy cows in 2000 to 852,841 in 2020, with milk production in 2020 being approximately 19.3 billion pounds. Results indicate that milk production in the Southern Ogallala Aquifer region is valued at $3.4 billion in direct economic output, generating a total regional economic contribution of approximately $7.6 billion. Milk processing has a value of $3.4 billion in direct economic output, generating a total regional economic contribution of $4 billion. Combining production and processing, a total direct economic output of $6.8 billion results in a total economic contribution of $11.6 billion for the dairy industry in 2020. Overall, milk production and milk processing contribute to approximately 10,305 in direct employment, generating 31,431 total jobs in the region.

Direct water usage is estimated at 62,095 acre-feet for the area, accounting for 3.3 percent of the overall water used in dairy farms. The majority of the water use is indirect, and a large portion of that is imported virtually through crops from other parts of the country as the Southern Ogallala Aquifer region demands more feedgrains than the amount of supply that is available locally. However, in this study, all indirect water was accounted for, regardless of the origin, for a total indirect water usage estimate of 1,832,598 acre-feet. Note that this estimate would be much lower if only considering crops grown and fed from within the Southern Ogallala Aquifer Region. Gauging the regional economic contribution for milk production against direct water use results in approximately $121,859 in economic output generated per acre-foot of water, while indirect water use results in approximately $4,129. The value when combining direct and indirect water use is $3,994 in economic output per acre-foot.

Water is a vital resource for all agricultural production, and most of the study area solely relies on the Ogallala Aquifer as the primary water source. Estimated water use is increasing, and the Ogallala Aquifer's withdrawals vastly exceed the recharge rate. Growing concerns about the reduction of water may have people questioning whether the economic benefits of the dairy industry justify the water use. This study provides awareness of the current economic contribution that the dairy industry brings to the regional economy. Overall, this analysis suggests that the dairy industry in the Southern Ogallala Aquifer region increases the economic activity, employment opportunities, and the value of water. The continued growth of the dairy industry may continue to benefit the region because, as water-levels decline and irrigated agricultural crop production shifts to dryland, dairies and milk processing facilities are a higher-value use of water than traditional crop production in the region. Processing facilities such as the new Cacique and Hilmar continue to emerge in the region, suggesting that the dairy industry will continue to grow, as will the industry's economic contribution.

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CHAPTER 1: INTRODUCTION

Throughout the last two decades, the dairy industry in the Southern Ogallala Aquifer Region has continued to grow substantially. The region's many favorable attributes, such as weather, labor, land, and resource availability, are why the dairy industry continues to expand in this region. Many environmental pressures in other states have also greatly influenced the migration of dairy farmers from across the United States. Less stringent environmental policies continue to attract dairy producers to migrate into the region (Guerrero et al., 2019). The region continues to evolve with the growing presence of dairy farms, calf raising operations, complimentary dairy processing facilities, and dairy servicing industries such as milk testing services, milk weighing services, and milk truck transportation, to name a few.

Irrigated land availability greatly influences dairy presence because of the potential for forage crop production predominantly conserved as silage, the predominant forage used in dairy rations in the region. Silage is commonly grown near dairy farms because of the ideal moisture content desired for the fermentation process. Additionally, due to the high water content of silage, producers find that sourcing local is the most economical option in terms of transportation costs. Organic dairy farms also greatly benefit from irrigated land availability due to organic regulations requiring pastureland for grazing.

Since the dairy industry is labor-intensive by nature, job opportunities are boosting the regional economy. Additionally, allied industries significantly influence the regional economy by providing more employment opportunities. Labor availability has recently increased in the U.S. due to nonimmigrant North American Free Trade Agreement (NAFTA) professionals known as trade NAFTA (TN) visa programs for dairy farm workers. With an appropriate professional degree, citizens from Mexico or Canada can travel to the United States for job opportunities for up to three years with the ability to renew their visas continuously (USCIS, 2021).

While local groundwater officials continue to develop methods to conserve water for future generations, water scarcity concerns continue to grow. Water is used in dairies directly as drinking water for cattle and facility maintenance. Water is also used by dairies indirectly through crop production, which is fed to cattle. The amount of water used directly and indirectly on dairy farms varies by location and management styles. Individual practices set by producers play a prominent role in the overall water usage of the farm. Growing efforts to reduce water usage in dairies has led to many producers using innovative techniques to recycle water in some way, shape, or form. Thus, many operations have incorporated methods that modify cleaning and maintenance techniques to reduce water pumped from the aquifer. Some water conservation methods include,

- water used to clean equipment and pens is collected and reused multiple times before entering retention ponds,
- effluent from retention ponds in dairies commonly being applied to crop acreage to lessen the impacts on the aquifer, and

- water used to cool down milk in milking equipment being reused for facility maintenance.

Farms will continue to incorporate methods that best suit their practices as water availability diminishes. Additionally, the amount of water utilized per farm depends on the size and composition of the farm. According to industry specialists for the Texas High Plains, cows are estimated to use about 65 gallons per cow per day; this is assumed for the entire region in the study (Kiel, Amosson, Beach, 2020).

Indirect water use depends on which crops are available to producers and the type of feed produced. With the large number of dairies located in the region and other competing livestock operations, not all feed is produced in the region. Thus, imports from other states are needed. This study estimates indirect water use as a total estimate from crops grown outside of the region as well as within the region.

Many studies are conducted evaluating groundwater aquifer use because of concern that water from the aquifer will cease to exist as many groundwater aquifers utilized for agriculture around the world are under great stress. Awareness of the dairy industry's demand for water as well as the regional economic contribution generated can help stakeholders such as policy-makers, groundwater planning groups, and the general public by providing them essential information to help guide decisions regarding this scarce natural resource. Education on the matter can also provide awareness, for producers, to their environmental responsibility to society. The overall objective of this study is to evaluate the dairy industry regarding water use relative to their contribution to the regional economy. Specifically,

- estimate direct water use for milk production
- estimate indirect water use for milk production
- use a model to evaluate the regional economic contribution of milk production and processing, and
- analyze the value of water generated per unit of water by dairies using the regional economic contribution along with direct and indirect water use estimates.

CHAPTER 2: LITERATURE REVIEW

It is important to understand what research has been done and how it was conducted to have a better understanding of the best methods to use for this study. This section reviews existing articles related to the dairy industry’s contribution to the economy and water usage. Although limited literature related to the research exists, it provides valuable insight on how to best evaluate economic contributions as well as many other factors pertaining particularly to the dairy industry.

The objective of a study performed by Guerrero and Amosson (2013) was to determine the contribution of irrigation to employment, income, and economic output in the Texas High Plains while also calculating an estimate of water usage. In this study, IMpact Analysis for PLANning (IMPLAN) was used to estimate the regional economic effects of two scenarios, one baseline irrigated scenario, and an alternative dryland scenario. Direct sales were input into IMPLAN, and an analysis-by-parts was used for more specific results, based on actual data collected from budgets of the region. Direct, indirect, and induced effects were calculated using multipliers to estimate backward-linked economic effects. Additionally, the effects of locally produced commodities on processing sectors were also estimated. The results indicated a considerable economic decline of an estimated $4.3 billion in industry output and $1.4 billion in value-added, affecting more than 34,600 jobs (Guerrero and Amosson, 2013). Unquestionably, this study indicated the importance of irrigated crop production in the region. It is safe to assume that this number has increased with the growth in the region and the transition of acreage being allocated for silage production, which requires irrigated land.

Silage is a major component of most dairy rations and requires large amounts of irrigated land for production. A large amount of indirect water use comes from silage consumption. Almas et al. (2017) assessed forage quality effects on milk yield for corn and sorghum silage. Water usage was evaluated to determine the silage that required the least amount of water but fulfilled the nutritional requirements of the livestock in the region and yielded higher milk production. It was mentioned in the article that corn silage is a high water use crop, while sorghum silage is a low water use crop. Ordinary least squares regression was used to predict the effects of forage quality on milk yield using crude protein, lignin, starch, and true in-vitro digestibility as explanatory variables (Almas et al., 2017). With the continued growth of the dairies in the Southern Ogallala Aquifer region, silage demand will continue to increase.

Almas et al. (2017) concluded a statistically significant relationship between milk production per ton of forage dry matter and forage quality in both corn and sorghum silage. Milk yield increased by 16% when feeding corn silage compared to sorghum silage. Alternatively, sorghum silage was more profitable, in terms of irrigation, to feed and required less water than corn silage (Almas, 2017). Since the majority of silage production is near dairy farms, sorghum production is a good alternative option that can reduce the amount of water pumped from the Ogallala Aquifer.

The dairy industry in New Mexico is a significant contributor to the regional economy of the Southern Ogallala Aquifer Region. Cabrera et al. (2008) quantif the economic contribution that dairy farming and dairy processing plants have in New Mexico. Linkages between dairy farms and processing plants were identified using the IMpact analysis for PLANning (IMPLAN) software and data. Results indicated that counties in New Mexico, including Curry, Lea, and Roosevelt, where dairy farms are concentrated, make up a large part of the state's total economic contribution (Cabrera et al., 2008). This study is similar to the presented study and counties that the authors evaluated are also included in the Southern Ogallala Aquifer Region.

Guerrero et al. (2019) explored the dairy industry expansion in the Texas High Plains over the Ogallala Aquifer region. The focus of the study was to compare a dairy presence vs. no dairy presence and identify how water usage, crop mix, and local economy are affected in a single year. Direct water usage was analyzed using 65 gallons per cow per day, and inventory numbers were calculated through milk production as reported in Milk Marketing Order 126. Milk production was estimated using an average of 70 lbs. of milk per cow per day. Indirect water usage was computed using a model dairy cow ration. Regional crop enterprise budgets were used to calculate the acreage needed to produce the total tons of feed demanded by the dairy industry. A Statistical Analysis System (SAS) was used to test the significant differences in the number of acres of crops grown in a single year, the employment rate, annual payroll, or the number of establishments for each NAICS sector. Due to some of the changes being too small to identify using the previous method, data were further analyzed using specific North

American Industry Classification System (NAICS) codes. Lastly, spatial data was analyzed using GeoDa to view the distribution of dairies in the region (Guerrero et al., 2019). Milk production is also a factor needed for evaluation in the present study. However, a review of historical data indicated milk production averages increased over time, and thus, an alternative method of using historical average production is used.

Guerrero et al. (2019) found that total water is minimally affected by dairies. A tradeoff analysis identified that while there is an increase in irrigation requirements to fulfill the feed demand for dairies, overall irrigation did not increase due to acreage being allocated for silage production. The comparative analysis between dairy vs. no dairy presence identified a slight increase in total water use in the scenario of no dairies present. The main factor identified was that silage crops utilize less water because they are harvested sooner than regular grain crops. Subsequently, results indicated that dairies locate close to counties with access to irrigation and milk processing plants. It was suggested that future research of factors that influence the establishment of the location of dairies would be beneficial to predict future dairy growth accurately (Guerrero et al., 2019).

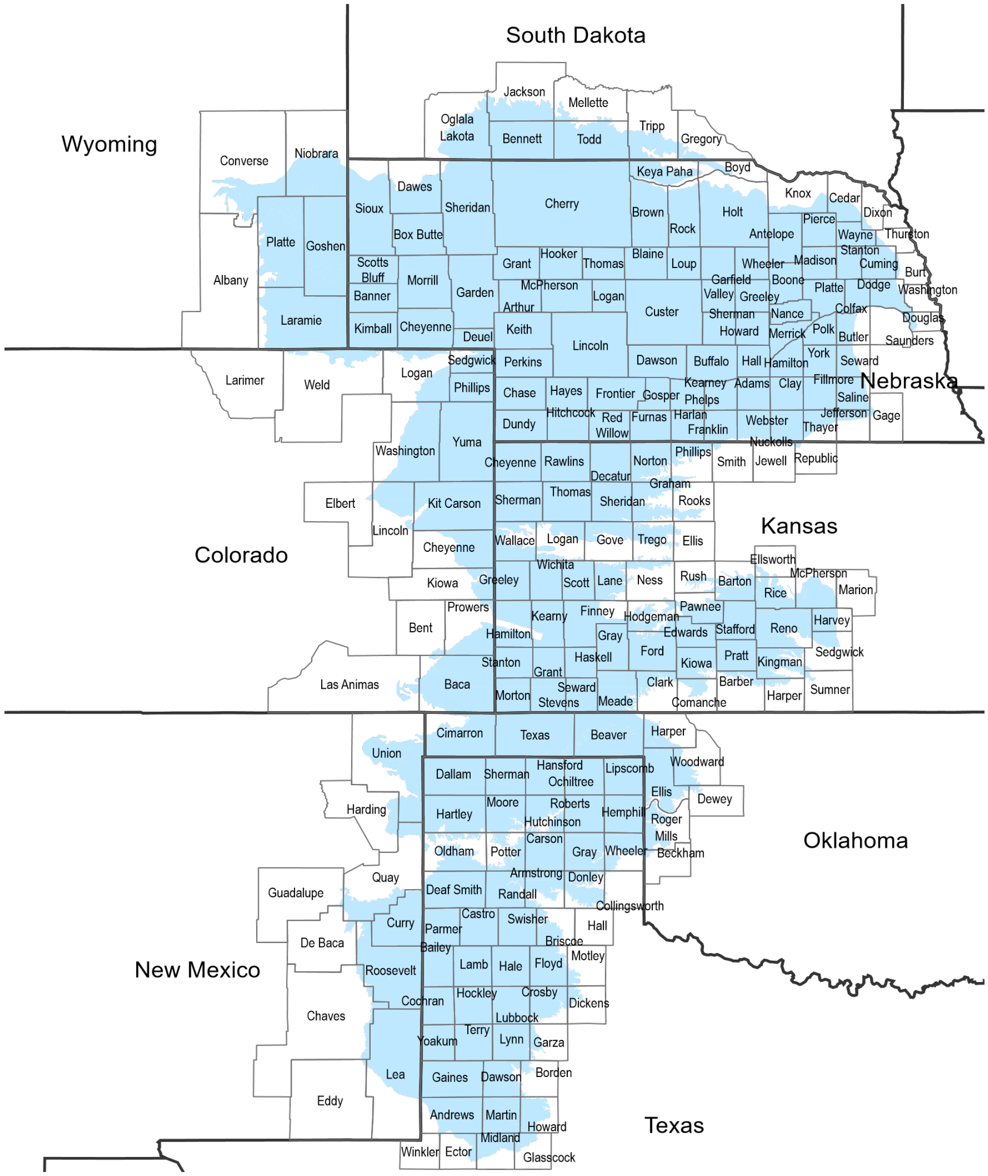
Guerrero, Amosson, and Jordan (2012) examined the contribution of the dairy industry in the Southern Ogallala Region. The objective of the study was to identify the regional economic contribution of the dairy industry and complementary industries on the region and assess whether the economic benefits justify water use. Direct and indirect water usage was estimated using inventory of milk cows in the region, by National Agricultural Statistic Service districts, and an example ration for a dairy cow. Direct water usage was calculated using the estimate of 55 gallons of water per cow per day. The majority of the dairy cow example ration was made up of silage. Due to the moisture content of the silage desired for storage and fermentation purposes, it was assumed that silage was produced locally within the region, decreasing the availability of land that could be used for other crops. Regional economic contributions were measured using a computer analysis program, IMPLAN (IMpact analysis for PLANning). The direct, indirect, and induced effects were estimated for three economic measures: industry output, value-added, and employment (Guerrero, Amosson, and Jordan, 2012).

Guerrero, Amosson, and Jordan (2012) concluded that water usage exceeded the recharge rate for several decades, causing a steady decline in the aquifer. However, as dairies continue to move into the region and raise the value of water, the total amount of water used will remain relatively constant. Due to the contribution of $4.3 billion in annual economic output and 13,400 jobs, milk producers and processors represented a relatively high value for water use. Overall, the study concluded that the dairy industry had a minimal impact on water usage, increased employment opportunities, and increased economic activity in the Southern Ogallala Region. The continued growth of the dairy industry in the region was expected to benefit the area by offsetting losses from traditional crop production shifting to dryland (Guerrero, Amosson, and Jordan, 2012).

Similar to Guerrero, Amosson, and Jordan (2012), an overall evaluation of the dairy industry is conducted in this study. The dairy industry in the Southern Ogallala Aquifer region is evaluated based on regional economics and water usage. Due to the continual growth of the dairy industry, this study provides important updates, as well as better estimation of factors such asmilk cow inventory using a more region-specific method of data collection, similar to the study conducted by Guerrero et al. (2019).

CHAPTER 3: DATA AND METHODS

The Ogallala Aquifer extends from South Dakota to Texas and sustains eight states (Texas, New Mexico, Oklahoma, Kansas, Colorado, Nebraska, Wyoming, and South Dakota) (Figure 1). The aquifer underlines approximately 175,000 square miles and has a saturated thickness that ranges from zero feet to about 1,200 feet, depending on the location (McGuire, 2017). The presence of dairies in this study area has grown significantly over the last several decades. The growth in the region's dairy industry coincides with the continued growth of the dairy processing industry as cheese and dry milk manufacturing industries significantly increased production (Guerrero, Amosson, and Jordan, 2012). Press releases on new dairies as well as upcoming cheese plants in the region suggest that the industry's growth will continue.



Source: Layer derived from USGS principle aquifer web service and developed by Mark Stewart (ArcGIS, 2021)

Study Region

This study focuses on the Southern Ogallala Aquifer region, which includes everything below the northern state line of Kansas. This includes 46 counties in Texas, nine counties in Colorado, six counties in New Mexico, 52 counties in Kansas, and seven counties in Oklahoma (Table 1). Counties were selected based on an Ogallala Aquifer presence from an existing study (Gollehon and Winston, 2013). The inclusion of all these counties was to ensure that the dairy industry's presence throughout the region was captured in full. The majority of these counties rely on the Ogallala Aquifer as a main source for water. However, some bordering counties as well as counties central to the region may utilize other minor aquifers as well as surface water sources that are available to them, such as the counties in the more eastern part of the study region in Kansas.

Table 1. Counties included in the study area, by state

Texas (46)	Andrews, Armstrong, Bailey, Borden, Briscoe, Carson, Castro, Cochran, Crosby, Dallam, Dawson, Deaf, Smith, Dickens, Donley, Ector, 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, Yoakum
New Mexico (6)	Curry, Harding, Lea, Quay, Roosevelt, Union
Colorado (9)	Baca, Cheyenne, Kiowa, Kit Carson, Las Animas, Lincoln, Prowers, Washington, Yuma
Kansas (52)	Barber, Barton, Cheyenne, Clark, Comanche, Decatur, Edwards, Ellis, Ellsworth, Finney, Ford, Gove, Graham, Grant, Gray, Greeley, Hamilton, Harper, Harvey, Haskell, Hodgeman, Kearny, Kingman, Kiowa, Lane, Logan, Marion, McPherson, Meade, Morton, Ness, Norton, Pawnee, Phillips, Pratt, Rawlins, Reno, Rice, Rooks, Rush, Scott, Sedgwick, Seward, Sheridan, Sherman, Stafford, Stanton, Stevens, Thomas, Trego, Wallace, Wichita
Oklahoma (7)	Beaver, Cimarron, Ellis, Harper, Roger Mills, Texas, Woodward

Data Collection

Milk cow inventory data were estimated using multiple sources. Milk production by county was the primary source of data used to estimate lactating dairy cow inventory and data sources included Milk Marketing Order 126 (Texas and New Mexico) and Milk Marketing Order 32 (Oklahoma, Colorado, and Kansas) (Southwest Federal Milk Marketing Order 126, 2021; Central Marketing Area Federal Milk Marketing Order 32, 2021). These data were used along with milk production data per cow per day to obtain final lactating cow inventory estimates. These inventory was then adjusted to include dry cow inventory to obtain final dairy inventory estimates. Heifers estimates proved to be more difficult to obtain and were not included in this analysis. However, this method of inventory estimation still provides more complete information when compared to data available through the National Agricultural Statistics Service (NASS).

Dairy cow inventory was initially calculated using an estimate of 70 daily lbs. of milk per cow, in conjunction with the total milk production from each county annualized for the year, similar to previous research (Guerrero et al., 2019). These were used to estimate lactating dairy cow inventory for the states by year. However, an alternative data source provided more accurate production numbers per milking cow by location for Texas, Colorado, New Mexico, and the Lower Midwest (Kansas and Oklahoma) (Genske, Mulder and Company, 2021). These averages served as a better indicator of production by state and by year. Historically, this average has an upward trend growing from an average of 62 lbs. per cow per day in 2000 to 76 lbs. in 2020 as production techniques become more efficient. Aside from some earlier years in Colorado and the Lower Midwest area, average production per cow was not available. For these years, average production was calculated by increasing by 1% each year (USDA NASS, n.d.) (Table 2).

Table 2. Average milk production (lbs.) per cow per day by state and year

Year	TX	NM	CO & OK	KS
2000	60	62	64	62
2001	61	63	64	62
2002	65	66	65	63
2003	60	66	66	63
2004	65	66	66	64
2005	64	66	67	65
2006	65	67	68	65
2007	62	68	68	66
2008	67	67	70	69
2009	68	71	72	71
2010	68	69	72	70
2011	69	70	72	71
2012	71	70	72	71
2013	71	71	74	72
2014	72	73	75	76
2015	71	72	75	74
2016	70	71	77	74
2017	73	73	77	75
2018	74	73	76	75
2019	72	74	76	74
2020	72	72	77	76

Milk production was not reported for counties with less than three dairies in the publically available Milk Marketing Order databases for discretionary purposes. Thus, Texas and New Mexico milk production data were limited and did not include counties with less than three producers (Southwest Federal Milk Marketing Order 126, 2021). Consequently, these numbers underestimated total milk production and the resulting lactating cow inventory. However, it is considered to be the most accurate estimate of historical data available for these states. Personal communication allowed for estimated inventory in some counties with a known dairy presence for 2020 (Piñeiro, 2021). However, these estimates do not appear graphically as they were not provided historically and were only included in the 2020 inventory estimates used to evaluate the regional economic impact for that year.

More accurate milk production data for Kansas, Oklahoma, and Colorado were obtained through personal communication that included counties with less than three producers due to the data being obtained in aggregate form for all three states (Schoening, 2021). However, this did not allow for estimates on a per-state basis. Thus, estimates were obtained for Kansas (Harner, 2021) in order to separate Kansas estimates from Colorado and Oklahoma. According to Harner (2021), dairies began establishing in Western Kansas in 1995, and then experienced growth at an average rate of 4,000 cows per year until the year 2000, when there were 20,000 cows in the region. From 2000 to 2010, there was a continued growth, but at a slower rate of about 3,000 cows per year, leading to 50,000 lactating cows by 2010. From 2010 to 2020, inventory grew at a rate of about 7,000 cows per year to roughly 120,000 lactating cows. This was approximately 70% of the total lactating cows in Kansas in 2020 (Harner, 2021). These estimates for Kansas were subtracted from the aggregate Kansas, Colorado, and Oklahoma data provided to estimate a combined total of lactating cow inventory for Oklahoma and Colorado. Due to the smaller presence of dairies in Oklahoma and Colorado, these two states were combined throughout the study.

For more accurate final dairy cow inventory estimates, it was necessary to include dry cows. Thus, total dairy cow inventory were calculated assuming that dry cow inventory equals 15 percent of the total lactating cow inventory (Piñeiro, 2021). For example, lactating inventory for 2020 was 741,601 head; thus, dry cow inventory was calculated at 111,240 head, resulting in a total inventory of 852,841 dairy cows for the entire region (Figures 2 and 3).

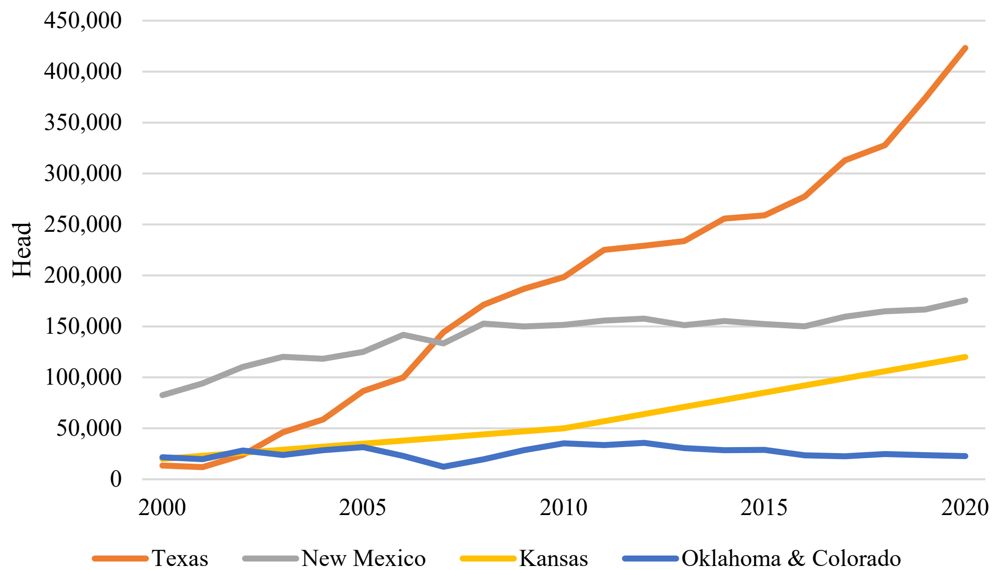


Figure 2. Southern Ogallala Aquifer Region dairy cow inventory by state, 2000-2020.

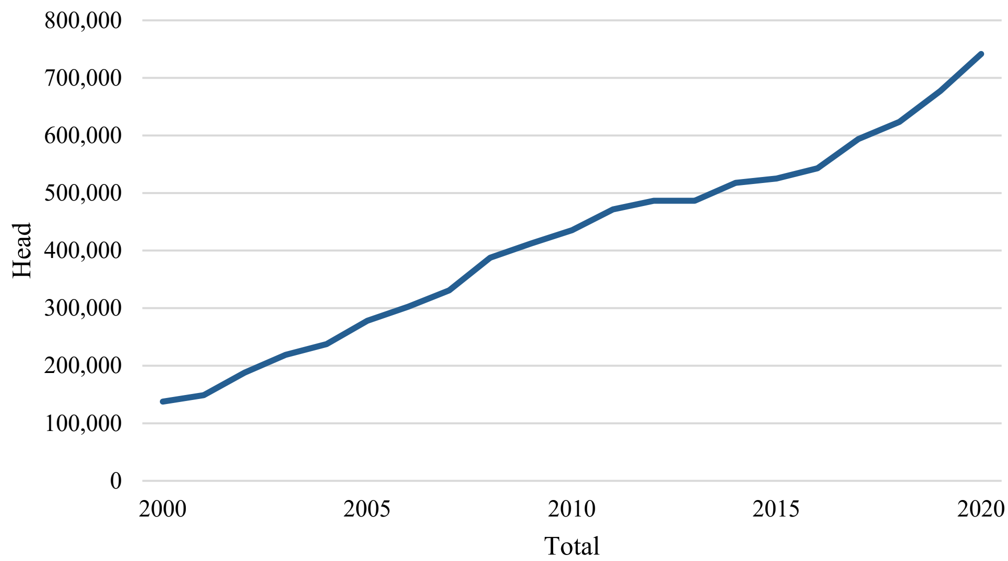


Figure 3. Southern Ogallala Aquifer Region total dairy cow inventory, 2000-2020.

Direct water usage was calculated using an average of 65 gallons of water per day per cow and the calculated estimated number of dairy cows in the region (Kiel, Amosson, and Beach, 2020). Water used in the production of feed is indirect water use. Indirect water usage was calculated using a simplified model ration (Table 3) (Piñeiro, 2021). This ratio is a combination of rations for dairies along the Texas High Plains and is assumed for the entire study region. Rations vary from dairy to dairy, based on the least cost options and availability of crops. Due to the differences in rations between lactating and dry cows, both were combined as a dairy cow unit. Indirect water usage was estimated by transforming the feed requirements into required acres of production and applying typical irrigation water use by crops. Average yields and water application by crop was retrieved from crop budget data (Texas A&M AgriLife Extension Service, 2020).

Table 3. Estimated model dairy ration for study area, 2020.

Dairy Ration			
	Lactating Dairy Cow	Dry Cow	Composite
Ingredient	Dry Matter (lbs.)		
Total Forage	**27.50**	**23.25**	**31.00**
Alfalfa	3.20	2.79	3.60
Grass hay	0.90	4.34	1.60
Crop residues [b]	0.40	3.72	1.00
Total Silage	23.00	12.40	24.90
Corn Silage	16.50	7.69	17.70
Sorghum Silage	1.00	1.61	1.20
Small Grains Silage	5.50	3.10	6.00
Concentrates [a]	**33.00**	**7.75**	**34.20**
Corn grain	14.74		14.74
Total	**60.50**	**31.00**	**65.20**

[a] Includes distillers grains, soybean meal, mineral mix, canola meal

[b] Includes corn stalks, wheat straw, peanut hay, and cotton gin trash

Data were collected from the IMPLAN database for economic output by sector for all counties, states, and the entire region (IMPLAN, 2018). These data were used to obtain an overview of where economic transactions occur for sectors 12 (dairy cattle and milk production), 82 (cheese manufacturing), 83 (dry, condensed, and evaporated dairy products), 84 (fluid milk manufacturing), 85 (creamery butter manufacturing), and 86 (ice cream and frozen dessert manufacturing). This database was used as an initial basis for estimating the direct value of sales by county.

Through communication with several processing plants in the region, more precise information was obtained concerning production and employment, specifically for the region's cheese and dry milk processing facilities. Production for processing facilities was collected, and economic output was calculated based on the average product price for ice cream, butter, whey, cheese, and dry milk (USDA AMS, n.d.). The calculated output was compared to data provided from IMPLAN for processing plants.

Certified public accountants who regularly work with dairy producers in the region provided average income and expense reports for more accurate regionalized results (Genske, Mulder and Company, 2021). The accounting data was used to create dairy budgets which were incorporated into IMPLAN using the template for industry spending patterns and labor income. This template was used for the analysis by parts technique performed in IMPLAN to calculate the regional economic contributions made by the dairy industry. Additional data was collected to modify IMPLAN, specifically the payroll cost for sector 12 (dairy cattle and milk production), using hired labor average costs and milk prices (USDA ERS, 2017; USDA NASS, 2020).

Manufacturing survey data were obtained to calculate payroll for all dairy processing sectors (82-86) using production workers' wages and sales (United States Census Bureau, 2019). Employment for sector two (grain) and sector 10 (all other crop farming) were modified to account for more accurate estimates of employment for crop production (Langemeier and Dhuyvetter, 2005). Employment for sector 467 (vet services) was modified to account for veterinarians in the region specifically working on dairy farms (Dall et al., 2013). Direct employment for milk production was adjusted to one employee for every 100 cows (Piñeiro, 2021). A comprehensive economic contribution study was used to avoid double-counting (Watson et al., 2015) and the steps taken are outlined in Appendix A.

CHAPTER 4: RESULTS

Water Usage

On average, each dairy cow unit requires approximately 117 lbs. (as fed) of feed per day. The primary ingredient to most dairy rations is silage; the ration consists of corn silage (50.6 lbs.), sorghum silage (3.4 lbs.), and small grain silage (17.1 lbs.), for a total of 71.1 lbs. of silage. Concentrates such as corn grain, distillers' grains, soybean meal, mineral mix, and canola mix make up the second majority of the ration. This ration results in 21.3 tons required annually per dairy cow unit and accounts for forage shrink. Regional feed demand for 2020 includes 622,574 tons of alfalfa, 282,988 tons of grass hay, 172,937 tons of crop residues, 7,871,114 tons of corn silage, 2,668,174 tons of small grain silage, 533,635 tons of sorghum silage, and 6,048,872 tons of concentrates. Therefore, the approximate total feed requirement is 18.2 million tons for the dairy industry in 2020 (Table 4).

Table 4. Estimated feed requirements for dairy operations in the study region, 2020.

	Dairy Cow Unit		Study Region
Ingredient	**Daily Ration as fed (lbs.)**	**Annual Ration as fed (tons)** [a]	**Feed Requirements (tons)** [b]
Alfalfa	4.00	0.73	622,574
Grass hay	1.82	0.33	282,988
Crop residues	1.11	0.20	172,937
Corn Silage	50.57	9.23	7,871,114
Sorghum Silage	3.43	0.63	533,635
Small Grains Silage	17.14	3.13	2,668,174
Concentrates	38.86	7.09	6,048,872
Total	**116.94**	**21.34**	**18,200,294**

[a] Assumes dry matter content of 90%, 88%, 90%, 35%, 88% for alfalfa, grass hay, crop residues, silages, and concentrates, respectively.

[b] Based on an estimated dairy cow inventory of 852,841 in 2020

Crop residues and some of the concentrates are not included in the indirect water use estimation. Crop residues include corn stalks, wheat straw, peanut hay, and cotton gin trash. Water use for crop residues is accounted for in the original crop production. In terms of concentrates, corn grain is the only concentrate that was broken out, for which indirect water use is calculated. Data for distillers' grains, soybean meal, mineral mix, and canola mix for the region were not provided separately. Thus, from the 18.2 million tons of feed required annually for the entire region (Table 4), approximately 14.7 million tons are used for the indirect water estimation (Table 5).

Table 5. Estimated indirect water use and corresponding irrigated crop acreage required by dairy operations in the study area, 2020.

	Feed Requirements (tons)	Yield/ Acre (tons)	Acreage	Irrigated Applied (ac-inch per acre)	Indirect Water (ac-feet)
Alfalfa	622,574	5.50	113,195	24.00	226,391
Grass	282,988	2.56	110,542	9.00	82,907
Corn Silage	7,871,114	27.00	291,523	20.00	485,871
Small Grain Silage [a]	2,668,174	10.00	266,817	10.00	222,348
Sorghum Silage	533,635	21.00	25,411	14.00	29,646
Corn Grain	2,699,041	6.30	428,419	22.00	785,435
Total	**14,677,526**		**1,235,907**		**1,832,598**

[a] Yield and irrigation application was obtained using triticale data (Texas A&M AgriLife Extension, 2020)

Results indicate total indirect water usage is 1,832,598 acre-feet, accounting for 96.7 percent of the total water use of the dairy industry in 2020; direct water use (62,095 acre-feet) makes up the remaining 3.3 percent. A more regional estimation can be obtained using only silage production (737,865 acre-feet), which would account for 38.9 percent of water usage in the dairy industry. Silage is obtained from within the region due to the high moisture content and transportation expense. On the other hand, grain may be transported from other regions of the country outside the Southern Ogallala Aquifer Region (e.g., dry ground corn from the Midwest region). Direct, indirect, and total water usage are presented in Figure 4.

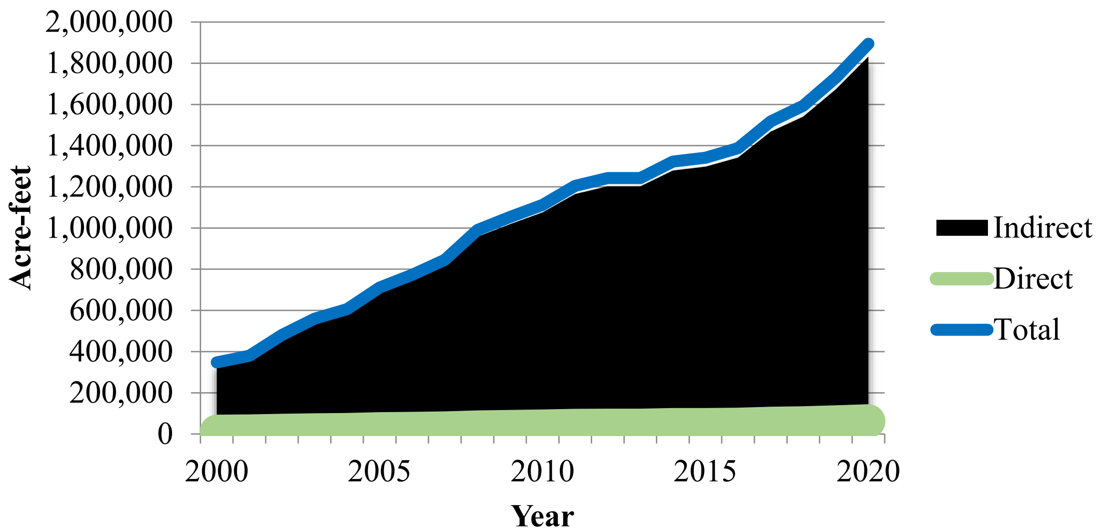


Figure 4. Southern Ogallala Aquifer Region estimated direct and indirect water use dairy cows, 2000-2020.

Regional Economic Contribution

An economic contribution refers to the gross change in economic activity associated with an industry, event, or policy in an existing regional economy (Watson et al., 2007). Ripple effects are estimated using the IMPLAN model, which shows economic sectors, directly and indirectly, related to the dairy industry. IMPLAN is an input-output economic model that traces interdependencies between economic sectors for a selected geographic region. The types of contributions presented are employment, value-added, and output. Direct, indirect, and induced effects are estimated with the IMPLAN model. Sales, income, and employment that are generated by operations that produce milk products are direct effects. The purchase of inputs, such as energy and transportation services used to produce and deliver milk products are indirect effects. Induced effects occur when dairy employees use their income to buy goods and services from restaurants and businesses.

Both milk production and milk processing facilities are present in the study region. Milk processing plants are not present in Colorado and Oklahoma. However, milk production (dairies) is present in all five states. The value of milk production is calculated using milk prices and milk production for each state (Table 6). Results indicate that milk production in the Southern Ogallala Aquifer region is valued at $3.4 billion in direct economic output (Table 7).

Table 6. Estimated milk production output by state, 2020.

State	Milk Production (lbs.)	Price (CWT)	Output
Colorado and Oklahoma	642,701,800	$18.20	$116,971,728
Kansas	3,381,840,000	$17.10	$578,294,640
Texas	10,647,012,697	$18.60	$1,980,344,362
New Mexico	4,626,487,945	$16.30	$754,117,535

Milk processing plants include fluid milk, dry milk, whey, and cheese manufacturers. Some of the manufactures of the region include fluid milk processing plants, Plains and Gandy's Dean Foods in Texas, Hiland Dairy Foods in Kansas, and DFA in New Mexico. Cheese processing plants such as Hilmar Cheese in Texas and Southwest Cheese in New Mexico. Dry milk processing plants such as Lone Star and Continental Dairy Facilities in Texas, Dairy Concepts Powder Plant (DFA) in New Mexico, and the DFA Powder Plant in Kansas. Milk processing has a value of $3.4 billion in direct economic output. The dairy industry in the Southern Ogallala Aquifer Region has a total direct economic output of $6.8 billion (Table 7).

Table 7. Value of milk production and processing in the Southern Ogallala Aquifer Region, 2020.

Region	Milk Production	Milk Processing	Total
Colorado and Oklahoma	$116,971,728	-	$116,971,728
Kansas	$578,294,640	$449,564,148	$1,027,858,788
New Mexico	$754,117,535	$1,475,176,424	$2,229,293,959
Texas	$1,980,344,362	$1,481,277,222	$3,461,621,584
Total	**$3,429,728,264**	**$3,406,017,794**	**$6,835,746,058**

Economic contributions vary by state. Texas contributes 50.6 percent due to having the highest milk production and representation of fluid milk, dry milk, and cheese processing sectors. New Mexico accounts for 32.6 percent of the total contribution, while Kansas contributes 15 percent. Colorado and Oklahoma do not have processing sectors in their region and have a small number of milk cows. Therefore, these states only slightly contribute to the overall region contribution (Figure 5). Detailed contribution data, by state, is presented in Appendix B.

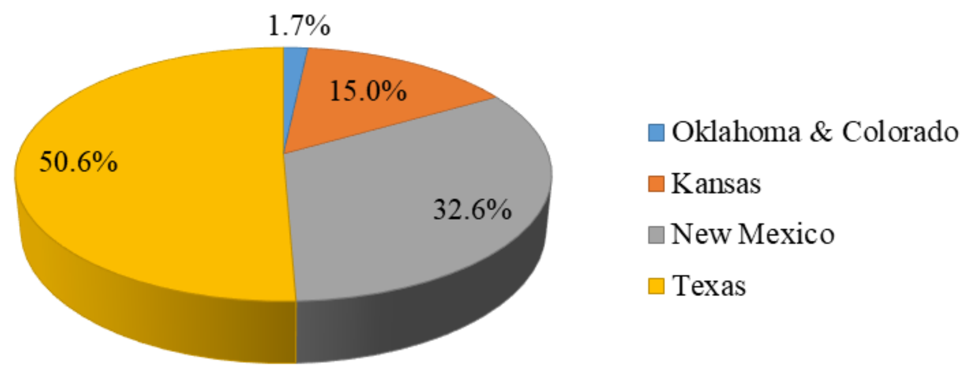


Figure 5. Percentage of the total economic contribution of the dairy industry to the Southern Ogallala Aquifer Region by state, 2020.

The overall economic contribution that the dairy industry provides to the study area extends beyond the direct effects. Results indicate that milk production in the Southern Ogallala Aquifer Region generates a total regional economic contribution of $7.5 billion, and milk processing generates an additional $4 billion. Overall, the dairy industry in the Southern Ogallala Aquifer Region has a total economic contribution of $11.6 billion for the dairy industry in 2020 (Table 8).

Table 8. Economic contribution of the dairy industry to the Southern Ogallala Aquifer Region, 2020.

	Direct	Indirect	Induced	Total
		Milk Production		
Output	$3,429,728,264	$3,148,409,872	$988,662,452	$7,566,800,588
Value Added	$687,998,071	$1,355,344,007	$546,161,013	$2,589,503,091
Employment	8,528	10,845	6,865	26,238
		Milk Processing		
Output	$3,406,017,794	$434,004,912	$172,230,714	$4,012,253,420
Value Added	$1,292,786,958	$210,692,757	$95,161,801	$1,598,641,516
Employment	1,776	2,222	1,194	5,193
		Total		
Output	$6,835,746,058	$3,582,414,784	$1,160,893,166	$11,579,054,008
Value Added	$1,980,785,029	$1,566,036,764	$641,322,814	$4,188,144,607
Employment	10,305	13,067	8,059	31,431

Regional Economic Contribution per unit of Water

When considering water conservation methods, stakeholders should be aware of the economic return that milk production has. This study combines indirect water from outside and within the region for a total indirect water usage estimate. This estimate would be much lower if only considering crops grown and fed within the Southern Ogallala Aquifer Region. Direct water usage is calculated at 62,095 acre-feet for the area, accounting for 3.3 percent of the overall water used in dairy farms. Indirect water use is calculated at 1,832,598 acre-feet, accounting for 96.7 percent of the overall water used in dairy farms. Milk production's $7.6 billion gauged against direct and indirect water use yields an estimated value of water used by dairies. Direct water usage alone generates $121,858 per acre-foot. Indirect water usage alone generates $4,129 per acre-foot. When combining direct and indirect water use, the value is $3,994 per acre-foot.

However, it is important to note that not all indirect water comes from the Ogallala Aquifer. A large portion of water is imported from other parts of the country through concentrates. A more regional value of water is obtained using direct water combined with indirect water from silage production only, which would lead to a water value of $9,459 per acre-foot. Silage accounts for 39% of total water use on dairy farms. Further research is needed to know precisely the percentage of crops utilized by dairies which are grown within the region.

CHAPTER 5: SUMMARY AND CONCLUSION

The dairy industry in the Southern Ogallala Aquifer region contributes significantly to Texas, New Mexico, Oklahoma, Colorado, and Kansas by providing approximately 10,305 jobs in direct employment, and generating 31,431 total jobs in the region. The total direct economic contribution of the dairy industry is approximately $6.8 billion, generating a total economic contribution of approximately $11.6 billion in 2020.

Continued water withdrawals from the Ogallala Aquifer is inevitable. Water is a vital resource for all agricultural production, and the majority of the dairy industry in the study area relies on this aquifer as the primary water source. Growing concerns about the reduction of water may have people questioning whether the economic benefits of the dairy industry justify the water use. This study suggests the dairy industry in the Southern Ogallala Aquifer Region has minimal impact on water availability while increasing economic activity, employment opportunities, and the value of water.

With water availability in the Ogallala Aquifer diminishing, dairy producers should focus their efforts on stewardship of their land. Efforts made by producers to decrease the amount of direct water use could greatly influence overall water usage for the industry. Strategies to conserve water should be made by producers and policymakers while also considering the region's economic viability.

Cheese processing plants continue to expand in the region. The addition of the new Cacique cheese plant in Amarillo, Texas, and the addition of the Hilmar Cheese plant in Dodge City, Kansas suggests that the dairy industry in the region will continue to grow. This growth will contribute more extensively to the region's economy. Additionally, as water levels decline and irrigated agricultural crop production shifts to dryland, dairies and milk processing facilities may be a higher-value water use than traditional crop production in the region.

Limitations

Some limitations exist with the research provided that hinder accurate results. Due to many factors, the number of dairy cows in the region is challenging to calculate. Counties with less than three producers in the area are not included in this study due to confidentially for producers. Texas and New Mexico inventory are limited to data available in the online database. However, these two states remain the two largest contributors to the region's economy. Thus, if data were available, the overall economic contribution estimated could be more significant than what is reported in this study. Colorado, Oklahoma, and Kansas milk production data was limited to a total milk production rather than milk production by state. Because of this, Colorado and Oklahoma inventory is a remaining amount of the total milk production data provided after considering Kansas inventory estimates.

The data to calculate inventory is milk production is limited to average production per cow. Production averages vary by genetics, health, and feed. Although, this study includes reliable sources of data for average milk production per cow. Inventory is estimated, and actual inventory could vary.

There is a lack of information on the number of dairy heifers in the area. Therefore, this study does not include heifers due to the variance between farms raising their heifers or purchasing them from heifer-raising facilities outside of the region. Thus, this study does not include water usage for calves and heifer raising facilities.

It should be noted that a large portion of indirect water use is expected to be imported virtually through crops from other parts of the country as the Southern Ogallala Aquifer region demands more feedgrains than the amount of supply that is available locally. However, all indirect water is accounted for in this study, regardless of the origin (crops grown within the region and outside of the region) to get total indirect water use.

Employment data from the IMPLAN database does not correctly capture the number of dairy employees. Employment for milk production was adjusted to one employee for every 100 cows. This estimate is limited to employees only working with dairy cows and not dairy heifers. Calf raising facilities commonly require a significant number of employees due to calf feeding practices and daily care.

Future Research

This study focuses solely on the water use by dairies and does not include water usage by milk processing plants. Additional research is needed to calculate the amount of water used by milk processing facilities to fully account for water usage for the entire dairy industry.

One major change unaccounted for in this research is the coronavirus disease (COVID) and its effects on milk production and milk processing facilities. The worldwide pandemic disrupted milk production and movement through the supply chain. Some producers were forced to dump milk due to the unavailability or slowed production of processing plants. Worker shortages and increased production costs could be factors that can leave a lasting effect on the region. However, future research is necessary to determine the impact on the dairy industry during the pandemic.

Some producers are currently using practices that help limit the amount of water pumped directly from the Ogallala Aquifer. Future research could focus specifically on the methods and practices in place and the effect they have on water usage. Detailed methods and data on this topic could further increase the number of participants. Dairy producers can make decisions that affect everyone who benefits from the water available from the Ogallala Aquifer. Information on these topics could greatly influence their management practices.

Lastly, data suggests that the dairy industry will grow in the Southern Ogallala Aquifer Region. Continually updated research on the dairy industry's economic contribution is necessary to encourage policymakers to consider the region's economic viability regarding water usage.

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APPENDIX A

Steps for running dairy industry regional economic contribution in IMPLAN:

1. Customize → **study area data**
   a. When editing the following, under the edit options → edit totals then update per worker values
   b. **Employee compensation, proprietor income, other property type income, and tax on production and imports** for Sector 82 (cheese) & 83 (dry milk) & 84 (fluid milk) & 86 (ice cream) using 2018 & 2019 manufacturing survey data. Also, modify total **employment**, given knowledge of actual output and number of employees (calculate output per worker), then divide total output by that number to get total employment for sectors *where that information is known*. Otherwise, do not modify employment.
   c. **Employment** for Sector 2 (grain) and Sector 10 (all other crop farming) using a source from Bill Golden on employment for crop farming ($1,126,000/job – Langemeier and Dhuyvetter (2005))
   d. **Employment** for Sector 467 (vet services) (affects indirect effects) using information from U.S. Vet Workforce Study: Modeling Capacity

Utilization on employment for vet services for Dairy Cows (6.64% of employment for dairy portion of vet services)

2. Reconstruct Model
    a. Options → Construct → Multipliers
3. Customize → **commodity production**
    a. No byproducts for sectors 82 (cheese), 83 (dry milk), 84 (fluid milk) & 86 (ice cream) (this will eliminate overestimating effects)
    b. Set the output coefficient for each sector to 1 → Fixed → Balance → Save
4. Reconstruct Model
    a. Options → Construct → Multipliers
5. Customize → **trade flows**
    a. 0% RPC for sectors 12 (dairy and milk production), 82 (cheese), 83 (dry milk), 84 (fluid milk), & 86 (ice cream) (this eliminates double counting effects)
6. Reconstruct Model
    a. Options → Construct → Multipliers
    b. Check to see if the new RSC (second tab) is zero for those sectors.
7. Setup activities
    a. Import industry spending pattern and labor income for dairy cattle 12 (use analysis by parts)
        i. Activity Options → Import → From Excel and select the ISP and LI sheet from the IMPLAN template to import.

ii. ISP: event options → show all

iii. ISP: event options → change all → local purchase percentage → set to SAM model value

iv. ISP: event options → change all → event year → set to 2020

v. LI: event options → show all

vi. LI: event options → change all → event year → set to 2020

vii. LI: event options → change all → local purchase percentage → set to 100%

viii. Make sure 'Sum of Event Values' matches the sum of the coefficients in your template spreadsheet

ix. The impact will be set in the next step

b. Create new activity for sectors 82 (cheese), 83 (dry milk), 84 (fluid milk), & 86 (ice cream)

i. Enter the impact in 'Industry Sales' for each corresponding sector.

ii. Make sure event year is set to 2020 and LPP is set to 100%

iii. Event options → show all

8. Analyze scenarios

a. Set level at the gross sales for sector 12 (except 82 (cheese) & 83 (dry milk) & 84 (fluid milk) & 86 (ice cream), which is done in the previous step)

b. Run industry spending pattern and labor income together for sector 12.

9. Hand calculate (excel) direct effects using gross sales (output), production functions (value-added), and any employment data available or the IMPLAN employment direct multipliers for sector 12.

APPENDIX B

Table B-1. Economic contribution of the dairy industry in the Colorado and Oklahoma portion of the Southern Ogallala Aquifer Region, 2020.

	Direct	Indirect	Induced	Total
		Milk Production		
Output	$116,971,728	$101,781,441	$34,766,757	$253,519,926
Value Added	$27,154,680	$44,955,542	$19,206,456	$91,316,678
Employment	262	361	241	865
		Milk Processing		
Output	-	-	-	-
Value Added	-	-	-	-
Employment	-	-	-	-
		Total		
Output	$116,971,728	$101,781,441	$34,766,757	$253,519,926
Value Added	$27,154,680	$44,955,542	$19,206,456	$91,316,678
Employment	262	361	241	865

Table B-2. Economic contribution of the dairy industry in the Kansas portion of the Southern Ogallala Aquifer Region, 2020.

	Direct	Indirect	Induced	Total
		Milk Production		
Output	$578,294,640	$493,142,148	$173,631,268	$1,245,068,056
Value Added	$143,543,186	$216,034,524	$95,916,808	$455,494,518
Employment	900	1,733	1,206	3,838
		Milk Processing		
Output	$449,564,148	$74,489,238	$29,093,433	$553,146,819
Value Added	$168,578,504	$34,721,242	$16,074,017	$219,373,763
Employment	399	361	202	961
		Total		
Output	$1,027,858,788	$567,631,386	$202,724,701	$1,798,214,875
Value Added	$312,121,690	$250,755,766	$111,990,825	$674,868,281
Employment	1,298	2,094	1,408	4,800

Table B-3. Economic contribution of the dairy industry in the New Mexico portion of the Southern Ogallala Aquifer Region, 2020.

	Direct	Indirect	Induced	Total
		Milk Production		
Output	$754,117,535	$727,885,434	$210,906,386	$1,692,909,355
Value Added	$123,011,821	$310,784,163	$116,512,761	$550,308,745
Employment	1,173	2,486	1,464	5,123
		Milk Processing		
Output	$1,475,176,424	$178,368,382	$65,133,441	$1,718,678,247
Value Added	$568,755,898	$87,106,319	$35,988,402	$691,850,619
Employment	576	919	452	1,946
		Total		
Output	$2,229,293,959	$906,253,816	$276,039,827	$3,411,587,602
Value Added	$691,767,719	$397,890,482	$152,501,163	$1,242,159,364
Employment	1,749	3,404	1,916	7,069

Table B-4. Economic contribution of the dairy industry in the Texas portion of the Southern Ogallala Aquifer Region, 2020.

	Direct	Indirect	Induced	Total
		Milk Production		
Output	$1,980,344,362	$1,825,600,849	$569,358,041	$4,375,303,252
Value Added	$394,288,383	$783,569,778	$314,524,988	$1,492,383,149
Employment	4,867	6,265	3,954	15,089
		Milk Processing		
Output	$1,481,277,222	$181,147,292	$78,003,840	$1,740,428,354
Value Added	$555,452,556	$88,865,196	$43,099,382	$687,417,134
Employment	802	943	541	2,285
		Total		
Output	$3,461,621,584	$2,006,748,141	$647,361,881	$6,115,731,606
Value Added	$949,740,939	$872,434,974	$357,624,370	$2,179,800,283
Employment	5,669	7,208	4,495	17,371