Meeting the Regional Water Challenge

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INTRODUCTION

The Southern Ogallala Region dairy industry has seen rapid expansion in the last 15 yr as part of a milk production shift from the northeast and Midwest to the more arid Western region. Today, the dairy industry in 4 of the top 10 dairy states in the nation (CA, ID, NM, and TX) relies upon irrigation to grow the forage crops consumed in the rations fed to their cows. In addition, Washington state producers purchase a significant portion of the alfalfa hay they feed from the irrigated eastern portion of that state. The remaining top 10 milk producing states (WI, NY, PA, MN, and MI) are not as dependent upon irrigation to grow the crops used in their rations.

According to Kenny et al. (2009) the United States withdraws 460,000,000 acre-ft of water annually, with nearly one-half of the withdrawals for thermoelectric power generation and 31 % for crop irrigation. The top 3 states for water withdrawals are CA, TX, and NM with a combined total of 103,200,000 acre-ft/yr, with irrigation accounting for 53 % and livestock 0.54 % of the total water withdrawals in those states. As depicted in Table 1, the irrigation water application rate varies considerably from state-to-state, as does the type of irrigation and the source of the water withdrawals.

Although nationally about 80 % of total water withdrawn is from surface water, ground water reserves are critical in some areas (Kenney et al., 2009). The Ogallala aquifer is a major underground water resource stretching through portions of 8 states from SD; through western KS, eastern CO, and the OK panhandle; and into the panhandle of Texas and eastern NM. Currently it is estimated that the Ogallala contains < 3 billion acre-ft of water, with approximately 12 % of that storage capacity in TX and 1.5 % in NM (McGuire et al., 2003).

Table 1. Variation in source and application rate for irrigation water withdrawals in 2005 for select dairy states (Adapted from Kenny et al., 2009).

State	Irrigated land (acres, 000) Type of irrigation			Withdrawals (acre-ft/yr, 000) Source		Application Rate (Acre-ft/Acre)
	Sprinkler	Micro-irrigation	Surface	Ground-water	Surface water	
CA	1,460	2,650	4,940	9,660	17,700	3.02
ID	2,310	4.57	1,220	4,340	14,200	5.26
AZ	213	21	716	2,540	2,850	5.68
CO	1,150	3.16	1,880	2,600	11,200	4.56
KS	2,780	13.0	330	2,940	128	0.98
NM	408	19.1	441	1,420	1,730	3.64
OK	384	1.91	86.9	405	150	1.17
TX	4,060	74.7	2,070	6,860	1,890	1.41

REGIONAL WATER RESOURCES

Each state establishes its own laws governing the water resources within its borders. Most states have been developing some type of water management plan to conserve this precious resource. A summary of the agency responsible, key website(s), type of law, statutes governing, and some key facts follows for several states in the region.

Arizona

Agency Responsible: Arizona Department of Water Resources
Website: http://www.water.az.gov
Type of Law: Doctrine of prior appropriation
Statutes: Arizona Revised Statutes, Title 45
Key Facts: The groundwater Code was enacted in 1980 with the following goals - 1) control overdraft 2) allocate limited ground water resources, and 3) augmentation of groundwater supply through water supply development. There are 4 water resources in Arizona - Colorado River water, surface water other than Colorado River water, ground water, and effluent. Arizona has 4 *Active Management Areas* covering 13 % of the land and 80 % of the population. In *Irrigation Non-Expansion Areas* (**INA**), restrictions prohibit increasing the number of acres that are irrigated in the area.

Colorado

Agency Responsible: Colorado Division of Water Resources (also known as Office of State Engineer), Colorado Ground Water Commission, Colorado Water Conservation Board
Website: http://water.state.co.us/
Type of Law: Doctrine of prior appropriation
Statutes: State Constitution Article XVI, sections 5 to 8; Colorado Revised Statutes, Title 37: Water and Irrigation; and Ground Water Management Act of 1965
Key Facts: In 1879, CO passed the nation's first laws to distribute water to its citizens. There are 8 basins and 13 local ground water management districts within the basins. Each division has its own Water Courts System. Colorado water law also claims rainwater and prohibits its diversion to protect senior water rights.

Kansas

Agency Responsible: Kansas Department of Agriculture, Division of Water Resources
Website: http://www.ksda.gov/dwr/
Type of Law: Vested rights, pre-June 28, 1945 and doctrine of prior appropriation since
Statutes: K.S.A. 82a-702. Dedication of use of water. All water within the state of Kansas is hereby dedicated to the use of the people of the state, subject to the control and regulation of the state in the manner herein prescribed.
Key Facts*:* In 1917 the Kansas Water Commission was created with a division of irrigation established in 1919. Both were abolished in 1927 and the Division of Water Resources was established. The Kansas Water Office and Kansas Water Authority were created in 1981, replacing the Kansas Water Resources Board which had been established in 1955. The State Water Resources Planning Act was enacted in 1963.

New Mexico

Agency Responsible: New Mexico Office of the State Engineer
Website: http://www.seo.state.nm.us/
Type of Law: Doctrine of prior appropriation

Statutes: New Mexico Statutes, Chapter 72
Key Facts: All ground and surface waters belong to the public. The Water Resources Allocation Program (**WRAP**) is responsible with the State Engineer for administering the water rights program. The groundwater code was enacted in 1931. Currently 39 declared underground water basins exist within the state and NM has rights to water in 8 interstate stream basins.

Oklahoma

Agency Responsible: Oklahoma Water Resources Board
Website: http://www.owrb.ok.gov/util/waterfact.php
Type of Law: Doctrine of prior appropriation
Statutes: Oklahoma Statutes Title 82. Water and Water Rights; Title 785. Oklahoma Water Resources Board; Chapter 30. Taking and Use of Groundwater; and Chapter 20. Appropriation and Use of Stream Water
Key Facts: Oklahoma has 23 major groundwater basins with the largest being the Ogallala Aquifer. Original Oklahoma Groundwater Law was adopted August 26, 1949 and repealed July 1, 1973 when the Ground Water Act became effective.

Texas

Agency Responsible: Texas Commission of Environmental Quality, Texas Water Development Board (planning and project financing)
Websites: http://www.tceq.texas.gov/; http://www.twdb.state.tx.us/
Type of Law: Surface water – doctrine of prior appropriation after domestic and livestock uses, both perpetual rights and limited-term rights; Groundwater – rule of capture (supported by courts since 1904; Fipps, 2002)
Statutes: Texas Water Code
Key Facts: Groundwater law is based on English common law following a 1904 Texas Supreme Court ruling. Texas has 9 major and 20 minor aquifers. There are 7 major water basins as well. Currently there are 98 groundwater conservation districts and one is pending confirmation.

WATER USE FOR DAIRIES

To calculate the mix of forages being used on Texas Panhandle dairies, dairy producers in the region from Select Milk Producers, a milk marketing cooperative, were sent a one page questionnaire regarding the forages they raised and purchased to feed the dairy cows and heifers in their herd. Surveys from 14 milking herds were returned. Two herds had heifer operations associated with them that raised heifers for other individuals. One heifer operation had separate feed inventories. In the second operation, 7000 heifers from 6-12 mo were fed from the combined feed inventory. Roughage consumption by the heifers in this operation was estimated and removed from the remaining calculations. Estimates below are calculated after these adjustments.

The mean number of animals utilized in estimations across herds was 7643 (SD 3169) with total acres owned by these herds to grow feed ranging from 0 to 5616. These herds averaged 86.4 % of the cows *in milk*, which is comparable to industry standards. In addition, 1488 bulls/steers were in the herds. No adjustment for the bulls/steers was made since many herds use bulls in various reproductive roles. Total forage DM on a *per milking cow* basis was 42.5 lb/d (36.7 lb/d if total cows). This value includes the dry land small grains produced as well as forages from outside the area. Total irrigated acreage within Texas averaged 0.907 acres per milking cow or 0.78 acres per cow (milking and dry). Approximately 10 % of the total acreage or roughly 39 % of the double cropped acreage required per cow was irrigated using water captured in the retention control structure. Table 2 displays the weighted average number of acres of forages raised by the producer or purchased locally needed to feed either one milking cow or one adult cow in Texas Panhandle herds for one year. The feed required for the associated young stock and bulls/steers is attributed to the milking cow or adult cow.

Each year, Extension creates budgets for the various cropping enterprises in the Panhandle, which include average irrigation requirements. Currently, the estimated average irrigation requirement for wheat is 15 acre-in; grain sorghum, 14 acre-in; sorghum silage, 13 acre-in; cotton, 12 acre-in; corn silage, 22 acre-in; corn grain, 22 acre-in; and alfalfa, 24 acre-in (Amosson, personal communication). Although sorghum silage is estimated to need 1 acre-in less water than grain sorghum, no adjustments are recommended for wheat and corn being grown for silages despite the fact that these crops are harvested earlier than their grain counterparts.

By using the forage utilization data from the survey of Lager et al. (2011), the average water use to support the forage production requirements per milking cow and her replacement can be estimated (Table 3). The 17.8 acre-in/yr for the crops used for dairy is < 5 % more irrigation water than the 16.9 acre-in/yr use in Texas estimated by Kenny et al. (2009).

Table 2. Acres per milking cow or per total cows required to raise forages being fed (CS=Corn Silage; SS=Sorghum Silage; SGS=Small Grain Silage). Adapted from Lager et al., 2011.

	Mean	SE	Per Milking Cow and Replacement	Per Total Cows and Replacement
Irrigated Raised Forage, A				
CS	1155	258	0.31	0.268
SS	352	99	0.095	0.082
SGS	993	170	0.267	0.230
Alfalfa	357	124	0.096	0.083
Of Raised Forage Land, A				
Double Cropped Owned	920	215	0.229	0.198
Double Cropped, RCS Water	390	108	0.09	0.078
Irrigated Purchased Forage from Panhandle, A				
CS	425	170	0.09	0.078
SS	40	36	0.009	0.007
SGS	70	34	0.015	0.013

Table 3. Estimated average water use for crops to support the forage production for a milking cow and her replacement (CS=Corn Silage; SS=Sorghum Silage; SGS=Small Grain Silage).

Crop		Acre/cow/yr to grow forage	Acre-in required by crop	Acre-in required
SGS		0.28	14*	3.9
CS		0.4	20*	8.0
SS		0.1	13	1.2
Alfalfa		<u>0.12</u>	24	<u>2.9</u>
	Total	0.90		16.0Acre-in for 0.9 Acres or 17.8 Acre-in/Acre

*Since the acre-in required for silage production requires at least one less watering based on personal communications the acre-in required was reduced from the Extension budgets by 1 in for SGS and 2 in for CS.

IMPACT OF THE DAIRY INDUSTRY ON THE SOUTHERN OGALLALA

The arrival of the dairy industry in the Southern Ogallala Region has resulted in a change from traditional crops grown for grain to many of the same crops being grown for silage. Although the industry is having a strong positive effect on the regional economy, concerns have been expressed regarding the perceived use of water by the industry. The practice of double cropping has been questioned regarding additional strain on the limited water supply of the region.

A study was recently completed, which evaluated the impact dairies are having on the Southern Ogallala Aquifer and the impact of the dairy industry on the regional economy (Guerrero et al., 2012). The area in this study covers approximately 97,000 square miles, including portions of five states (CO, KS, NM, OK, and TX) starting at the northern border of Kansas and extending to just north of the Midland-Odessa area of TX. The area has 19.7 million acres of cropland with 7.3 million acres being irrigated. Starting in the mid-1990s, the dairy industry grew first in NM, followed by growth in western KS and then the Panhandle of TX. With the opening of the Leprino plant in Greeley, CO may be on the verge of an expansion, although that plant is just north of the study region.

The region has been a grain deficit area since the late 1970s when the fed beef industry developed. Since the mid-1980s there has been a decline in the number of irrigated acres producing feed grains, reflecting depletion of the aquifer; thus any increase in water use required by the dairy industry will have to be offset by decreases in existing operations or increases in imported feed grains rather than increased pumping from the aquifer.

There are both direct and indirect water use components. The direct water required for drinking and facility maintenance as well as the indirect water required to produce feed for the cattle was estimated. Overall, the water use by the dairy operations will have only a minor impact on the region's agricultural enterprises since the area was already a grain deficit area and the aquifer was already declining. The traditional cropping composition within a local region will be influenced to some degree by the introduction of a dairy facility; however that change could be as small as changing from corn for grain to corn for silage.

The dairy industry in the Southern Ogallala Region currently provides over $4.3 billion to the regional economy and 13,400 jobs as a result of the combined impact of the dairies and processors. When accounting for only the direct water use, dairies are a relatively high-value user for water generating over $93,000 per acre-ft. If both the direct and indirect water use is calculated the value is slightly more than $1,600 per acre-ft (Guerrero et al., 2012). In reality, this latter value is an underestimate, as a significant portion of the grains used by the dairies are imported; therefore a substantial portion of the indirect water use is "virtual" since the crop isn't grown in the region.

POTENTIAL METHODS TO DECREASE WATER USE

Based on National Agricultural Statistics Service data, the Southern Ogallala Region had 453,200 head of dairy cows in 2010. The region had 12.4 million acres of dryland crops and 7.4 million acres of irrigated land. Guerrero et al. (2012) estimated that the direct water consumption of the dairies would displace just over 22,000 acres or approximately 0.3% of irrigated cropland, much of which would have been required for the facilities on which the dairies are sited. If 100 % of the forages and concentrates required by the dairy industry were grown in the Southern Ogallala Region, approximately 1.6 million acre-ft of water would be required for indirect water use by the industry. Currently the region uses approximately 11 million acre-ft of water annually for all direct water use for livestock and crops, which is down from a peak of approximately 13 million acre-ft in 1976. In reality, the total water use in the region has been relatively constant since the early 1990s; however the proportion going to support the direct and indirect water use of the dairies is increasing. The challenge to the industry is how to decrease the total water use attributable to the industry while allowing continued economic growth.

Reduce alfalfa acreage

Since alfalfa has the largest irrigation water requirement of the forages being grown and it can be dried and transported greater distances as hay, producers in the Southern Ogallala Region might explore purchasing their alfalfa needs from outside the region instead of growing their own crop. However, even if 100 % of the alfalfa hay currently being grown in the area were imported into the region instead, estimated average water use for the crops grown in the area for dairy would only fall to 16.8 acre-in/acre.

Cease Double Cropping

The Table 3 estimate of the average water use for crops to support forage production assumed only one crop was grown on an acre per year. However, based on the survey results (Lager et al., 2011), 0.23 acre/cow/yr are double cropped. If the estimated water use is adjusted for double cropping, the irrigation water requirement could increase to over 25 acre-in/yr. This figure has not been adjusted for the 10 % of all acreage that is watered using effluent from the retention control structure or for the reduction in irrigation resulting from a reduced pre-watering requirement since a crop had recently been removed. Thus one realistic way to reduce the water use per acre is to cease double cropping.

There are additional factors which must be considered when making this decision. Many of the acres that are double cropped on dairies are actually being used to dewater retention control structures. Before arbitrarily stopping all double cropping the impact on nutrient flows must be computed. There is additional cost related for distributing the effluent over a more distant land base, as well as transportation costs to return necessary forages to the dairy. In some instances it may be more prudent to allow more remote acres to lie fallow and concentrate the growing of crops in close proximity to the dairy. Of course whether this is an option will depend upon how pumping regulations are written, the acreage controlled by an individual producer, and nutrient budgeting to optimize use of the organic matter produced on a dairy.

Switch to More Sorghum

There has been a great deal of discussion regarding switching to sorghum silage from corn silage to reduce the irrigation water required for growing forages. Each year, Texas AgriLife Research and Extension scientists conduct trials to evaluate the various hybrids. In 2010, a total of 56 forage sorghum varieties, 16 conventional and 32 BMR, were included in the trials (Bean et al., 2010). The forage sorghums received approximately 12 in of irrigation water in addition to 7.3 in of rainfall. The nonBMR sorghums had 5.8 % lodging at harvest while the BMR sorghums had 17.8 % lodging. The sorghum forage was harvested at soft dough stage (Bean et al., 2010). Select data from the trial is included in Table 4.

Corn silage trials were conducted in 2 different locations in 2010 (Xu et al., 2010). At the Halfway, TX location, 14.58 acre-in of irrigation water was used in addition to the 11.03 in of rainfall. The silage was harvested at an average 50 % milk line and analyzed using NIR by the Dairy One Forage Lab (Ithaca, NY). At the Etter, TX location, 17.73 acre-in of irrigation water was used in addition to 4.38 in of rainfall. No pre-watering was done at either site since soil moisture profiles were adequate at planting. Average select data across all corn hybrids by location are presented in Table 4.

Table 4. Select data from corn and sorghum silage variety trials conducted in 2010 (adapted from Bean et al., 2010; Xu et al., 2010) and calculation of tonnages per acre-in of water.

Crop	T/Acre-in Irrigation + Rain, 35 % DM	T/Acre-in Irrigation, 35 % DM	T/ac @ 35 % DM	% CP	% ADF	% NDF	% IVTD	% Starch	Milk, lb/T DM
NonBMR Sorghum	1.27	2.05	24.6	7.9	30.9	48.1	78.6	19.9	2,751
BMR Sorghum	1.20	1.92	23.1	8.1	29.6	46.8	81.5	16.9	2,917
Corn Silage, Halfway	1.18	2.07	30.3	9.0	21.3	36.6	78.7	40.9	2,999
Corn Silage, Etter	1.42	1.77	31.4	8.2	21.1	36.9	77.5	41.5	2,922

CP= crude protein; ADF=acid detergent fiber; NDF=neutral detergent fiber; IVTD= in vitro true digestibility; NDFD= %NDF digestible in 24 hr; Milk lb/t is a projection of potential milk yield/t;

One must be careful when evaluating yield data per acre-in of irrigated water, as it is highly dependent upon soil moisture prior to planting and subsequent rainfall. Although the typical Panhandle Extension budgets for corn require 22 in of irrigation, neither site required that much in the 2010 corn silage variety trials; while the sorghum silages were within 1 in of the Extension budget irrigation quantity. In contrast, the 2011 sorghum silage trials required 20.3 inches of irrigation water during the season since less than 2 inches of rain fell during the growing season and tonnages declined to 21.9 tons/acre for non-BMR and 20.1 tons/acre BMR sorghum silage at 65% moisture (Bean et al., 2011).

Grow Genetically Modified Drought Resistant Crops

Texas AgriLife Research scientist Wenwei Xu has been crossing temperate and tropically adopted varieties of corn in an attempt to create new hybrids that can perform well with limited irrigation. Ledbetter (2008) reported that when 20 experimental hybrids were grown with 100 or 75 % evapotranspiration (**ET**) irrigation rates, yields averaged 27.49 and 26.84 T/acre, respectively. In addition, Xu et al. (2007) has reported that the drought resistant hybrids have reduced aflatoxin in some environments.

In addition to university research, many commercial companies have been seeking to identify corn that is drought tolerant. For example, this year Pioneer Hi-Bred (2010) has introduced its Optimum® AQUAmax™ hybrid line. Depending upon regulatory approvals, Monsanto (2011) is planning to begin on-farm field trials in 2012 and launch its first biotech product in 2013.

Improve Efficiency of Irrigation

As illustrated in Table 1, irrigation application rates vary widely across the U.S. Although some of this is related to crop requirements, there are opportunities to enhance irrigation efficiencies to decrease the amount of water required to successfully grow crops. According to Benham (1998) conventional gated pipe irrigation has an efficiency of about 50 %, however by adding a reuse pit to the system the efficiency can increase to near 70 %. Another method to increase the efficiency is to irrigate using an every-other-furrow irrigation method which can reduce water requirements by 20 – 30 % (Benham, 1998). Most producers in the Texas panhandle have switched to center pivot systems, which Benham (1998) reported were 80 - 90 % efficient.

Schneider et al. (2001) compared 3 high efficiency irrigation methods: subsurface drip irrigation (**SDI**), low energy precision application (**LEPA**) and two spray irrigation methods – low elevation spray application (**LESA**) and mid-elevation spray application (**MESA**) on sorghum grain production. The crop was irrigated at 0, 25, 50, 75 or 100 % of the ET network recommendation. Although initial growing conditions were normal, the cumulative rainfall for the 4-mo growing season was only 49 % of the 60-yr average. The yields at the 25 and 50 % irrigation levels were significantly higher for the SDI; however at the 75 and 100 % levels, the LESA and MESA irrigation resulted in the highest yields leading the authors to conclude that for high efficiency irrigation methods optimal method may "vary more with the irrigation amount than with the application technology" (Schneider et al., 2001).

CONCLUSION

As water resources become more limited, competition for those resources will increase. This will become particularly true for the dairy producers in the western portion of the United States that are more dependent upon groundwater to grow forages. Depending upon location, producers have several alternatives to how they can reduce their water usage for forage production. They can reduce the forages they grow and import those forages from another area, provided the forages are available and an economical alternative; switch to a forage with lower water demands, such as sorghum; leave more acres fallow; cease double-cropping; or switch to a higher efficiency irrigation method, if possible.

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