Sorghum Silage to Sustain Dairy Industry in the Texas High Plains under Declining Aquifer

by

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Contributed Paper prepared for presentation at the **29th International Conference of Agricultural Economists (ICAE) "Agriculture in an Interconnected World"**
August 8-14, 2015 Milan, Italy

Abstract: Economic analysis of sorghum silage potential for the growing dairy industry was conducted and identified yield effect, water saved, feed requirement, acreage and production cost. More acreage, irrigation water and feed will be needed if sorghum silage is used to replace corn silage unless dryland sorghum silage yield is improved.

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Abstract:

The dairy industry in the Texas High Plains has grown rapidly and using water from Ogallala Aquifer to sustain their operations. The Ogallala Aquifer is the main source of water in the region and is declining. Local and state leaders are concerned about the future economic viability of the region and the appropriate use of its scares water resource.

Economic analysis of sorghum silage potential for dairy industry was conducted to identify yield effect, water saved, feed requirement, acreage and production cost. With water being a global issue, with rising demand as result of increasing population, and with increasing demand of silage from the expanding dairy companies, sorghum silage will be an economical feed alternative to replace corn silage.

Switching from irrigated corn silage to irrigated sorghum silage has the potential to save water and production cost. It has been estimated that switching 30,000 acres from irrigated corn silage, irrigated grain sorghum, and dryland grain sorghum to irrigated sorghum silage will result in economic benefit amounting to $4.904 million. There is potential to save 116,373 ac-ft. of water.

Keywords: Sorghum Silage, Texas High Plains, Ogallala Aquifer, Dairy Industry, Water Saving

JEL codes: Q12, Q13, Q15, Q25

1. Introduction

Texas Panhandle is often referred to as the cattle feeding capital of the world and the success of feedlot industry has attracted other businesses into the area. The favorable conditions that brought the cattle industry to the area are now attracting the hog (Almas et. al., 2004), dairy and cheese industries. The expansion in the livestock industry has prompted an increase demand for animal feed, which has led crop producers in Texas to increase input used in producing these crops; thus, increasing the amount of water pumped out of the Ogallala Aquifer. The expansion of the livestock industry, especially the dairy industry in Texas, has resulted in an increased demand for animal feed.

The milk production has increased from 19,646 pounds per cow in 2005 to 20,898 in 2009. The dairy cow population has also increased from 328,000 in year 2005 to 423,000 in 2009, increasing milk production from 6,444 million pounds in 2005 to 8,840 million pounds in 2009 with its value of $981.801 million in 2005 to $1.172 billion in 2009 (TASS, 2009). Guerrero et. al., 2012, have estimated the total economic impacts of dairy industry in the Texas High Plains to be more than $2.700 billion (Table 1). It is also reported that dairies are boosting the regional economy and creating jobs due to the labor intensive nature of the business, which requiring between 30 to 37 employees per 3,000 head of dairy. Water use in dairy can be classified as direct water use for drinking and facility maintenance, and indirect water use for growing feed and forage for animal feeding.

Corn silage, which is a major feed requirement in the dairy industry, is a high water use crop. With an increasing number of dairy animals, the amount of animal feed and irrigation water required also increases. The indirect water use comes from the Ogallala Aquifer. More than 90% of the water pumped from the Ogallala Aquifer irrigates at least one fifth of all U.S.

cropland (Stewart, 2003.). The Ogallala Aquifer now faces declining water levels and deteriorating water quality because rate of withdrawal is greater than rate of recharge. Alternative to corn silage is sorghum silage, which is a low water use crop. Sorghum has the greatest potential to produce large amounts of nutritious forage during the summer months and their inherent versatility allows them to fit into many different types of cropping and livestock operations (Marsalis, 2006).

2. Research Objectives

The research objectives of this study include evaluating the economic feasibility and potential water savings of replacing corn silage with BMR sorghum silage and estimating the economic benefits and water savings (current and future) to the region from adoption of this practice to sustain ever growing dairy industry in the region.

3. Scientific Background

Recent research has determined that fully irrigated forage sorghums (FS) can produce similar yields and quality as corn while requiring considerably less irrigation water (Bean et al., 2005). Forage yield and quality responses to varying levels of irrigation are not well documented for summer annual crops. Because many farmers in the region are producing crops on limited irrigation, it is necessary to develop response curves in relation to the water application for these forage crops and translate these response curves into value-cost sorghum silage production functions for economic analysis. Sorghum silage needs less water than grain sorghum because for sorghum silage to dry down to the proper moisture level for ensiling, irrigation has to be stopped several days to two weeks prior to harvest day when the moisture content will be between 65 to 70 % (Bean and Marsalis, 2012).

Fully irrigated sorghum silage will require 14-18 inches of water while grain sorghum will require 19-21 inches of water (Stichler and Fipps, 2003). According to the Texas Crop and

Livestock Enterprise Budgets 2012, corn silage is more expensive than sorghum silage; the price of corn silage is $53.47 per ton while sorghum silage is $48.12 per ton. Although there have been reports of large feed yards in the Texas Panhandle paying the same price for corn and sorghum silages (McCorkle, et. al., 2007).

4. Procedures Used:

The study includes counties in the Texas High Plains which mostly depend on the Ogallala Aquifer for irrigation (Stewart 2003; Almas, et. al. 2004). In Texas, irrigated corn silage acreage has ranged from 120,000 acres in 2008 to 220,000 acres in 2011. Due to drought conditions, there have been no dryland corn silage acres since 2008. Irrigated corn silage acres reduced from 220,000 in 2011 to 190,000 acres in 2012. This change may be due to severe drought conditions in Texas in 2011 and 2012.

On the other hand, dryland sorghum silage acres have increased from 40,000 in 2011 to 160,000 acres in 2012. Corn silage and sorghum silage are important ingredients of feed for dairy animals in the region. Two main types of forage sorghum hybrids, brown midrib (BMR) and non-BMR, are being utilized for silage production to be used as dairy feed. Many researchers, who have compared nutritional contents of both corn and sorghum silage, have concluded that many of the BMR, as well as some of the non-BMR varieties, have consistently had an in-vitro true digestibility (IVTD) value equal to or greater than that of corn (Bean and McCollum, 2006). The BMR trait in sorghum has significantly improved the digestibility level to be similar to corn (Contreras-Goven et al., 2010). Forage sorghum is highly competitive with corn on both yield and nutritive value. However, non-BMR forage sorghum produces more forage than BMR in most cases and also more than corn under limited water conditions (Marsalis et al., 2010). Milk production is also comparable to corn with conventional forage sorghums and higher with BMR due to higher digestibility of the fiber in the plant (Lusk et al., 1984; Oliver et al., 2004).

Two approaches were considered to evaluate the potential replacement of silage with sorghum silage. The first approach is based on meeting the requirements to feed current dairy cow inventory and estimated projections in the study area. The current inventory and projected dairy animals are based on the SB4 Livestock Projections Report (Marek et al., 2012). Each animal's daily feed requirement is based on the information available in the dairy publication (Guerrero et al., 2012). The estimated corn silage requirement was 3.6 million tons, which formed 70% of the total feed requirement of 5.2 million tons. The indirect water usage is calculated from the estimated feed required by dairy cow per day per year, which is the amount of water needed to grow these feed components in acre-feet. The number of cows in the inventory multiplied by the total irrigation water use will be the indirect water use. Based on data from the aforementioned sources, the following assumptions and scenarios were developed to estimate potential water saving (loss) if corn silage is replaced with sorghum silage under different conditions. We have assumed the following three scenarios:

1. Corn silage (CS) is fed to dairy cow (Baseline Scenario I)
2. Corn silage (CS) is replaced by sorghum silage (SS) at 100% (SS Scenario II)
3. Corn silage (CS) is replaced by 50% irrigated sorghum silage and 50% dry land sorghum silage (SSDS Scenario III)

The second approach is to compare the cost of production of corn silage with sorghum silage under different scenarios in order to estimate the economic benefit of switching from feeding corn silage to sorghum silage. The estimated positive benefit will generate additional profit to the dairy producers. In addition to total production cost approach, total revenue above variable cost for alternative crops was also used to estimate relative economic benefits of switching from corn silage to other options available to the area producers.

5. Results and Discussion

Most of the water used in producing the feed requirement came from the irrigated field. The baseline scenario estimated total indirect water use by dairy cow in 2010 was 222,675 ac-ft. when corn silage was part of the feed mix as shown in Table 2. Table 3 shows the projected cow inventory, estimated water use, and the required acres of land needed to cultivate to meet the required forage. The required acreage increases as the cow inventory and feed requirement increases. The indirect water usage constitutes 94% of the total water use by dairy cow when corn silage is used. The direct water use of dairy cow also increases as the inventory of dairy cow increases and is projected to increase by 200% from 2010 to 2060.

The total acreage of sorghum silage required if corn silage is replaced by sorghum silage (SS Scenario) is shown in Table 3. The sorghum silage feed required 4 million tons annually, which was 11% more than corn silage fed in 2010. The reason for the increase in sorghum silage required was because the corn silage yield of 27 tons per acre is greater than sorghum silage yield of 20 ton per acre. Forage sorghum has 80% to 90% of the energy value of the corn silage on a dry matter basis; therefore, 1.11 pounds of sorghum silage will have the same energy level as one pound of corn silage (Rick, 1994).

For the year 2010, the amount of total indirect water needed when sorghum silage was used to replace corn silage increased by 11,189 ac-ft. The is due to more acreage (66,850 acres) of sorghum silage that needs to be cultivated in order to meet the amount of feed provided by corn silage. Furthermore, the table also shows the projected acreage of sorghum silage required if sorghum is used wholly, which increases as the dairy inventory increases. The indirect water use for both corn silage and sorghum silage increased with the same proportion of 43% from 2010 to 2020 as the dairy population increased from 214,850 to 307,644.

The amount of water that can be saved at different yield levels is shown in Table 4. The amount of water saved increased as sorghum level increased. For year 2010, if the corn silage yield was assumed to be at 27 tons per acre while the yield of sorghum silage was at 22 tons per acre, the amount of water saved will be 10,071 ac-ft. This means that as the yield of sorghum increases, the amount of acreage required decreases and more water is saved when corn silage is replaced by sorghum silage. Sorghum yield increase will reduce the acreage cultivated and more water will be saved. At 27 tons per acre for corn silage and 23 tons per acre for sorghum silage, 19,315 ac-ft. of water will be saved. An increase in sorghum silage yield will result in more water savings.

Scenario three (SSDS) assumes corn silage is replaced by 50% irrigated sorghum silage and 50% dry land sorghum silage. For the year 2010, the feed requirement component from sorghum silage was 4 million tons, Table 3. Therefore feed requirement from the 50% irrigated sorghum silage can be calculated by multiplying percent to be contributed by irrigated sorghum silage and the total feed requirement expected from sorghum irrigated. This will result in 2 million tons of irrigated sorghum silage that can be produced. The remaining 50% can be produced from dry land. The yield from dry land sorghum was 3.02 tons per acres (6.8MgDm/ha) (McCuistion el.at., 2009). The number of dry land acreages to produce 2 million tons of sorghum silage will be 663,759 acres. As yield from irrigated acreage increases, the estimated area of dry land cultivated with sorghum silage decreases. Table 3 shows the projected amount of water that can be saved. The amount of water saved will depend on the yield of sorghum silage. For 2010, if the initial yield of corn silage per acre is 27 tons and the yield of sorghum silage increases from 20 to 22 tons per acre, 116,373 ac-ft. of water will be saved (Table 5). The acreage cultivated will be half of the number in Table 4.

5.1 Cost of Production Approach

Table 6 shows the total cost of production at different yield levels. For the year 2010, the cost incurred on corn silage was $118.704 million with 27 tons per acre yield. With sorghum silage yield at 20 tons per acre, $111.068 million would be incurred and it will result in a production cost savings of $7.636 million when sorghum silage replaces corn silage. Sorghum silage yield can be significantly increased with improved varieties such as brown midrib (BMR) sorghum. In which case, with sorghum silage yield at 22 tons per acre and corn silage yield at 27 tons per acre, savings in production cost will increase to $17.733 million ($118.704 - $100.971).

5.2 Cost vs. Water Saving Analysis

The cost of production for corn-sorghum combination was higher than the cost of production when sorghum silage was used to replace all of the corn silage acres. For year 2010, assuming yield at 27 tons per acre for corn silage and 20 tons per acre for sorghum silage, total cost of production is $109.321 million (Table 7) compared to $118.704 million given in Table 6. This will result into savings of $9.383 million in the cost of production and potential water savings of 6,124 ac-ft. The corn-sorghum silage combination cost of production is less than the cost incurred for corn silage production. $9,383 million and 11,7461ac-ft. of water can be saved if a 50-50 corn-sorghum combination is used instead of corn silage at the aforementioned given conditions. At 22 tons per acre of sorghum silage and 27 tons per acre of corn silage, $27.852 million can be saved in year 2010 in addition to 10,071 ac-ft. water saving.

5.3 Return Above Variable Cost Approach

In addition to the total production cost approach, total return above variable cost (RAVC) on a per acre basis for alternative crops is also calculated using Texas A&M AgriLife Crop and Livestock Budgets for 2012. Return above variable cost is then used to estimate relative economic benefits of switching from corn silage to other options available to the area producers. Table 8 has the estimated gross revenue, total direct expenses, and return above variable cost for four alternate crops being grown in the study area. The alternate crops included in this analysis were irrigated corn silage, irrigated sorghum silage, grain sorghum, and dryland grain sorghum. The return above variable cost for each crop selected depends on the gross revenue and irrigation cost. Per acre RAVC for irrigated SS, irrigated CS, irrigated GS and dryland GS was $619.02, $788.28, $389.75 and $121.04 respectively. The marginal returns as we change to other crops are also shown. When we shift from irrigated SS to irrigated CS, the return is negative (-169.26). However, when we move from dryland GS and irrigated GS to irrigated SS the marginal change is positive with $497.98 and $229.27 respectively.

Relative economic benefits of the two options to switch acres from CS and dryland GS and from irrigated GS to irrigated SS are presented in Table 9. The first option represents the producers changing from corn silage to irrigated sorghum silage. When irrigated sorghum is used to replace irrigated corn silage, $9.285 million is realized in revenue using 15,000 acres of irrigated sorghum silage. The net benefit from the dryland grain sorghum is $0.726 million. The relative benefit is the difference between the total revenue from irrigated sorghum silage and the summation of revenue from irrigated corn silage and dryland GS. The economic benefits of the irrigated sorghum silage from the other two alternatives are $1.465 million. The second option shows the economic benefit when irrigated grain sorghum is switched to irrigated sorghum silage.

6. Conclusions and Recommendations

Economic and sensitivity analysis is conducted for different scenarios to know the effects of yield on the amount of water saved, feed requirement, acreage to cultivate and cost of production. The cost of production for corn silage is higher than the cost of production for sorghum silage. The amount of water to be saved with respect to the substitution conditions and combinations depend mainly on improvement in the yield of sorghum silage and the price paid for it. An increase in sorghum silage yield will save more water, reduce acreage cultivated, and decrease the cost of production per acre. Dairy companies using sorghum silage will be able to save more on sorghum silage compared to corn silage, because sorghum silage is cheaper to cultivate and buy than corn silage. More acreage, irrigation water, and feed requirement will be needed if sorghum silage is used wholly to replace corn silage unless there is an increment in yield per acre of sorghum silage between 24-26 tons per acre. More water can also be saved if the yield per acre of dryland sorghum silage can be increased substantially, the cost of production can be reduced in relation to the high number of dryland sorghum acreage needed to meet the feed requirement through the irrigated sorghum-dryland combination. More research efforts should be focused on the BMR forage sorghum to improve yields especially under limited water conditions to make them more competitive with corn and conventional sorghums. With water scarcity being a global issue, with rising demand as a result of increasing population, and with an increasing demand of silage from the expanding dairy companies, sorghum silage is an economical feed alternative to replace corn silage.

Switching from irrigated corn silage to irrigated sorghum silage has the potential to save water because sorghum silage uses less water than corn silage. This change may also result in significant production cost savings. It has been estimated based on the return above variable cost analysis that switching 30,000 acres from irrigated corn silage, irrigated grain sorghum, and dryland grain sorghum to irrigated sorghum silage will result in an economic benefit amounting to $4.904 million and some water savings.

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Table 1. Economic impacts of the dairy industry in the Texas High Plains, 2010.

	Direct	Indirect	Induced	Total
	Milk Production			
Output '000'	$863,466	$382,235	$82,195	$1,327,896
Value Added '000'	$128,684	$132,742	$46,988	$308,414
Employment	3,005	1,665	760	5,430
	Milk Processing			
Output '000'	$666,559	$112,653	$33,219	$812,431
Value Added '000'	$188,413	$53,752	$18,970,349	$261,134
Employment	428	513	307	1,248
	Total			
Output '000'	$1,530,025	$494,887	$115,415	**$2,140,327**
Value Added '000'	$317,097	$186,492	$65,959	**$569,548**
Employment	3,434	2,177	1,067	**6,678**

Table 2. Estimated indirect water use required by dairy operations in the study area, 2010

	Alfalfa	Corn Grain	**Corn Silage**	Soybean	Total
Feed requirement (tons)	380,285	739,084	**3,607,332**	180,474	4,907,174
Yield /acre (tons)	5.5	6.3	**27**	1.43	
Acreage	69,143	117,315	**133,605**	126,206	486,045
Irrigation Applied(ac-in/acre)	24	22	**20**	16	
Indirect water (ac-ft.)	138,285	215,077	**222,675**	168,274	744,312

Table 3. Dairy cow inventory, silage acres required for feed, and water use, 2010-2060.

Description\Year	2010	2020	2030	2040	2050	2060
Total dairy cows	214,850	307,644	339,831	375,386	414,661	458,042
Corn silage (CS) acres	133,605	191,309	211,325	233,434	257,858	284,834
Total Feed (ton with CS)	3,607,332	5,165,343	5,705,771	6,302,725	6,962,155	7,690,520
Sorghum silage (SS) acres	200,455	287,032	317,063	350,235	386,879	427,353
Total Feed (tons with SS)	4,009,101	5,740,637	6,341,256	7,004,696	7,737,571	8,547,058
Water Req. (ac-ft. with CS) **Scenario I**	222,675	318,848	352,208	389,057	429,763	474,723
Water Req. (ac-ft. with SS) **Scenario II**	233,864	334,870	369,907	408,607	451,358	498,578
Water Req. (ac-ft. with SSDS) **Scenario III**	**116,932**	**167,435**	**184,953**	**204,304**	**225,679**	**249,289**
Water Saving Potential **Scenario I-III**	**105,743**	**151,143**	**167,255**	**184,753**	**204,084**	**225,434**

Table 4. Comparison between corn silage and sorghum silage at different yield level using water use, acreage required for 100% corn silage replacement by sorghum silage in year 2010

Corn Silage			Sorghum Silage		
Yield/acre (tons)	Acres Required	Irrigation applied (ac-ft.)	Yield/acre (tons)	Acres required	Irrigation applied (ac-ft.)
27	133,605	222,675	20	200,455	233,864
28	128,833	214,722	21	190,910	222,728
29	124,391	207,318	22	182,232	212,604
30	120,244	200,407	23	174,309	203,360
31	116,366	193,943	24	167,046	194,887
32	112,729	187,882	25	160,364	187,091
33	109,313	182,188	26	154,196	179,896
34	106,098	176,830	27	148,485	173,233

Assume 14 inches of irrigation water was applied to sorghum silage and 20 inches of irrigation water was applied to corn silage.

Table 5. Acreage, water use and water saved with 50% irrigated SS and 50% dryland SS

Corn Silage			Sorghum Silage			water saved at 50% irrigated sorghum silage (ac-ft.)
Yield/acre (tons)	Acres required	Irrigation applied (ac-ft.)	Yield/acre (tons)	Acres required	Irrigation applied (ac-ft.)	
27	133,605	222,675	20	100,228	116,932	105,743
28	128,833	214,722	21	95,455	111,364	103,358
29	124,391	207,318	22	91,116	106,302	101,016
30	120,244	200,407	23	87,154	101,680	98,727
31	116,366	193,943	24	83,523	97,443	96,499
32	112,729	187,882	25	80,182	93,546	94,336
33	109,313	182,188	26	77,098	89,948	92,241
34	106,098	176,830	27	74,243	86,616	90,214

Assume 14 inches of irrigation water was applied to sorghum silage and 20 inches of irrigation water was applied to corn silage.

Table 6. Production Cost Comparison between corn silage and sorghum silage 2010

Corn Silage (CS)			Sorghum Silage (SS)			Difference in cost CS and SS (Million $)
Yield/acre (tons)	Acres required	Cost (Million $)	Yield/acre (tons)	Acres required	Cost (Million $)	
27	133,605	118.704	20	200,455	111.068	7.636
28	128,833	114.464	21	190,910	105.779	8.685
29	124,391	110.517	22	182,232	100.971	9.546
30	120,244	106.834	23	174,309	96.581	10.253
31	116,366	103.387	24	167,046	92.557	10.831
32	112,729	100.156	25	160,364	88.855	11.302
33	109,313	97.121	26	154,196	85.437	11.684
34	106,098	94.265	27	148,485	82.273	11.992

Production Cost $888.47 per acre CS sprinkler irrigated and $554.08 per acre SS sprinkler irrigated

Table 7. Acreage required, expected cost of irrigation and amount saved when 50-50 corn-sorghum silage combined at different yield levels

Corn Silage			Sorghum Silage			Total Cost (CS and SS) Million $
Yield/acre (tons)	Acres required	Cost (Million $)	Yield/acre (tons)	Acres Required	Cost (Million $)	
27	66,802	59.352	20	90,183	49.969	109.321
28	64,417	57.232	21	85,889	47.589	104.822
29	62,195	55.259	22	81,985	45.426	100.685
30	60,122	53.417	23	78,420	43.451	96.868
31	58,183	51.694	24	75,153	41.641	93.334
32	56,365	50.078	25	72,147	39.975	90.053
33	54,657	48.561	26	69,372	38.438	86.998
34	53,049	47.132	27	66,802	37.014	84.146

Assume 14inches of irrigation water is applied to sorghum silage and 20inches of irrigation water was applied to corn silage.

Table 8. Return above variable cost ($ per acre) for four alternate crops using 2013 budgets.

	Irrigated SS	Irrigated CS	Dryland GS	Irrigated GS
Gross revenue	1134.00[1]	1620.00[2]	265.00[3]	795.00[4]
Total direct expense (excluding irrigation)	457.78	743.72	143.96	343.65
Irrigation(natural gas)	57.20	88.00	0.00	61.60
Total direct expense	514.98	831.72	143.96	405.25
Returns above variable cost (RAVC)	619.02	788.28	121.04	389.75
Returns relative to irrigated SS		-169.26	497.98	229.27

Note: Gross revenue for the various crops is based on the following yield prices and quantities [1]Revenue based on $54/ton price and 21.0 tons yield. [2]Revenue based on$60/ton yield and 27.o tons yield. [3]Revenue based on $10.60/cwt. and 25.0 cwt. Yield and [4]Revenue based on $10.60/cwt. and 75.0 cwt. yield. Based on natural gas price of $4.4/MCF

Table 9. Estimated relative economic benefit for two options for increasing SS cultivation

Option I (50% of the acres switching from CS and dryland GS)					
A Total additional acres of irrigated SS	50.00%	*	30,000	=	15,000
B Total RAVC for irrigated SS	15,000	*	619.02	=	$9,285,300
C Total RAVC for irrigated CS (60% of 15,000)	9,000	*	788.28	=	$7,094,540
D Total RAVC for dryland GS(40% of 15,000)	6000	*	121.04	=	726,240
E Total RAVC for corn and GS (C+D)	$7,094,520	+	$726,240	=	$7,820,760
F Relative economic benefit (B-E)	$9,285,300	-	$7,820,760	=	**$1,464,540**

Option II (50% of the acres switching from irrigated GS)					
G Total additional acres of irrigated SS	50.00%	*	30,000	=	15,000
H Total RAVC for irrigated SS	15,000	*	619.02	=	$9,285,300
I Total RAVC for irrigated grain sorghum	15,000	*	389.75	=	$5,846,250
J Relative benefit in RAVC (H-I)	$9,285,300	-	$5,846,250	=	**$3,439,050**
K Total economic benefit (F+J)					**$4,903,590**