Water Management Strategies for Reducing Irrigation Demands in Region A

Prepared for

Agricultural Sub-Committee
Panhandle Water Planning Group

By

Dr. Stephen H. Amosson
Dr. Lal K. Almas
Fran Bretz
Dustin Gaskins
Bridget Guerrero
DeDe Jones
Thomas Marek
Leon New
Nick Simpson

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Summary

Stephen H. Amosson[1]

In Senate Bill 1, the Region A Agricultural Demands and Projections Committee identified seven potential water management strategies for evaluation to reduce irrigation demand. These strategies included the use of the North Plains Evapotranspiration Network (NPET) to schedule irrigation, changes in crop variety, irrigation equipment efficiency improvements, changes in crop type, implementation of conservation tillage methods, precipitation enhancement and conversion of irrigated land to dryland. Each of these strategies is presented in Table 1 with the assumed water savings and implementation schedule presented in the Senate Bill 1.

Table 1 - Estimated Water Savings and Implementation Schedules for Agricultural Water Conservation Strategies Proposed in Senate Bill 1, Region A

Water Management Strategy	Assumed Annual Regional Water Savings (in/ac)	Assumed Baseline Use Year 2000	Goal for Adoption 2010	Goal for Adoption 2020	Goal for Adoption 2030	Goal for Adoption 2040	Goal for Adoption 2050
Use of NPPET	2	20%	70%	90%	90%	90%	90%
Change in Crop Variety	2	10%	40%	70%	70%	70%	70%
Irrigation Equipment Changes	3	55%	75%	95%	95%	95%	95%
Change in Crop Type	5	0%	20%	40%	40%	40%	40%
Conservation Tillage Methods	2	50%	60%	70%	70%	70%	70%
Precipitation Enhancement	1	0%	100%	100%	100%	100%	100%
Irrigated to Dryland Farming	12-14	0%	5%	10%	15%	15%	15%

The focus of this study was to revisit the strategies in a more detailed analysis. An effort was made to fully describe and document each strategy, refine the potential water savings, identify the cost of implementation and the potential impacts to the Region from implementing the strategy. Hopefully, this analysis will prove useful to the Regional Planning Group in evaluating the effectiveness of these strategies and provide information to assist in prioritizing the various strategies in the implementation process.

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[1] Regents Fellow, Professor and Extension Economist, Texas Cooperative Extension, Amarillo, TX 79106.

Based on the research conducted, some of the assumptions on potential water savings and strategy implementation schedules were altered before the proposed strategy was evaluated. A summary of the changes that were made to the various strategies is given in Table 2. For a more detailed discussion of the changes consult the individual strategy papers.

Table 2 - Changes to Senate Bill 1 Water Management Strategies.

Strategy	Change
Use of NPET	Water savings were reduced to 1 in/ac. Implementation was reduced to 10% in 2000 and increased 7½% per decade until it was assumed to level off at 50% after 2050.
Change in Crop Variety	The water savings from converting from long season corn and sorghum varieties to short season was specifically identified at 4.1 in/ac and .65 in/ac respectively. The proposed implementation schedule for this strategy remained unchanged.
Irrigation Equipment Changes	In SB1, it was estimated in 2000 that 55% of the irrigation systems were efficient (LESA, LEPA and SDI). This was revised to 78.5%. The implementation schedule was altered to reflect the revised baseline. LEPA and SDI were projected to increase 2% and ½% every decade until the 95% level of efficient systems is reached. The calculated saving from this strategy was 6.3 inches per acre.
Change in Crop Type	Converting irrigated corn acreage to irrigated cotton, sorghum and soybean acreage equally as proposed in SB1 was again used and resulted in an estimated 8.3 inches per acre compared to the 5 inches per acre estimate in SB1. The proposed conversion of irrigated soybean and sorghum to irrigated wheat (SB1) was eliminated based on a lack of projected water savings. The proposed strategy implementation schedule remained the same.
Conservation Tillage Methods	Water savings from implementing conservation tillage was reduced from 2 to 1.75 inches per acre. The implementation schedule remained unchanged.
Precipitation Enhancement	Water savings estimates and implementation schedule remained unchanged from SB1.
Irrigated to Dryland Farming	The strategy of converting some of the marginally irrigated crops (wheat, sorghum and cotton) to dryland as proposed in SB1 remained unchanged. Estimated water saving per acre was 10-10.7 inches compared to 12-14 inches used in SB1.

Methodology

Water savings, implementation cost and change in gross crop receipts were estimated for each proposed water management strategy identified in the Senate Bill 1 planning effort. All strategies were evaluated over 60-year planning horizon as identified in the Senate Bill 2 planning effort using Farm Service Agency (FSA) irrigated acreage for the Region as the base. Water availability was assumed to remain constant in measuring the impacts of the various water conservation strategies.

Implementation costs were defined as the direct costs associated with implementing a strategy whether these costs would be bourn by producers and/or the government. The change in gross crop receipts generated under the alternative strategies was estimated using five year averages for yields and prices in the Region. All costs were evaluated in current dollars.

Results

Cumulative water savings, implementation cost and direct regional impacts as expressed by the change in gross crop receipts for each of the water conservation strategies are presented in Table 3. The change in crop type was estimated to generate the largest amount of water savings, 8.7 million ac-ft, which was 8.3% of the total irrigation water pumped over the 60-year planning horizon. Implementing this strategy was expected to cost 46.0 million dollars resulting in an average cost of $5.25 per ac-ft of water saved. However, achieving these water savings came at an additional cost. The move to lower productive crops resulted in a loss of 2.1 billion dollars in gross crop receipts or $235.85 per ac-ft of water saved over the planning horizon.

Table 3 - Estimated Water Savings and Costs Associated with Proposed Water Conservation Strategies in Region A.

Water Management Strategy	Cumulative Water Savings (WS) ac-ft	WS/Total Irrigation Demand %	Implementation Cost (IC) $1,000	IC/WS $/ac-ft	Direct Regional Impact (DRI)[1] $1,000	DRI/WS $/ac-ft
Use of NPET	2,065,469	1.96	8,100	$3.92	+	+
Change in Crop Variety	6,658,309	6.32	-	-	-1,548,584	-$232.58
Irrigation Equipment Changes	4,124,398	3.91	169,608	$41.12	-	-
Change in Crop Type	8,709,995	8.26	46,000	$5.25	-2,054,000	-$235.85
Conservation Tillage Methods	2,135,882	2.03	1,098	$0.51	-	-
Precipitation Enhancement	4,105,680	3.89	25,800	$6.28	+	+
Irrigated to Dryland Farming	5,157,272	4.89	39,000	$7.54	-406,000	-$78.72

[1] +indicates an anticipated positive impact that was not quantified.

The change to shorter season corn and sorghum varieties yielded the second largest water savings of 6.7 million ac-ft or 6.3% of the total pumped. However, changing crop variety led to a reduction in yields that resulted in a loss in gross cash receipts of 1.5 billion dollars or $232.58 per ac-ft of water saved.

Converting marginally irrigated land to dryland production yielded water savings of 5.2 million ac-ft or 4.9% of the total pumped. The estimated change in land values resulted in an implementation cost of 39 million dollars and a resultant cost of $7.54 per ac-ft of water saved. Loss in gross receipts was estimated to be 406 million dollars or $78.72 per ac-ft of water saved.

Additional conversion of non-efficient irrigation delivery systems in the region, such as, furrow and MESA to more efficient systems (LESA, LEPA or SDI) resulted in a savings of 4.1 million ac-ft (3.9% of total irrigation water pumped). Investment in these more efficient systems and reinvestment as they wore out resulted in an implementation cost of 170 million dollars. This translates into a cost of $41.12 per ac-ft of water saved, by far the most expensive of the strategies considered from an implementation cost standpoint. However, this strategy was not expected to have any adverse effects on gross receipts, thus having a neutral impact on the regional economy.

The precipitation enhancement strategy was projected to save 4.1 million ac-ft under the assumption that increased rainfall would result in an equal reduction in pumping. The estimated implementation cost associated with this strategy was 25.8 million dollars resulting in a cost of $6.28 per ac-ft of water saved. This strategy should yield a positive impact to gross receipts in the region since additional rainfall will occur not only on irrigated land but on dryland and pasture operations increasing their productivity. No estimate of these positive externalities is provided.

Increasing the level of conservation tillage practices yielded water savings of 2.1 million ac-ft or 2.0% of total irrigation water pumped. The cost of the increased conservation tillage given the implementation schedule was estimated at $1,098,000 resulting in the lowest implementation cost per acre-foot of water saved ($0.51). Increasing conservation tillage acreage was assumed to have a neutral effect on gross crop receipts.

Increased use of the NPET to improve the efficiency of irrigation scheduling was estimated to save 2.1 million ac-ft or approximately 2.0% of total water pumped. Implementation costs were estimated at 8.1 million dollars resulting in the second lowest cost per ac-ft of water saved, $3.92. It should be noted that the water savings assumed a 1 in/ac savings which may or may not be accurate for the region. Results of a very limited, previous survey of NPET users indicated that just as many producers increased pumping from use of the NPET (increased irrigated acreage) as decreased water usage. A study of the California network yielded a significant increase in returns from a combination of water savings and yield increases, but the amount of water savings achieved was omitted from the study report.

Summary and Conclusions

The purpose of this study was to provide more substantial documentation of the agricultural water conservation strategies proposed in the Senate Bill 1 planning effort including refining estimates of water savings and implementation costs. In addition, the potential direct effect to the region’s economy was evaluated via the anticipated change in gross crop receipts. Additional regional impacts derived from the indirect and induced effects caused by the change in crop receipts were not evaluated. The impact of each strategy was evaluated using the revised Region A Senate Bill 2 parameters of a 60-year planning horizon and an irrigated acreage base constructed from Farm Service Agency (FSA) data.

Prioritizing the seven strategies will depend on how the agricultural committee wants to weigh the various decision variables, i.e., water savings, implementation costs and regional impacts. The two strategies that yield the largest water savings, changing crop type and change in crop variety, are projected to generate a significant negative impact to the regional economy, -$235.85 and -$232.58 per ac-ft of water saved, respectively. The third leading water saving strategy, conversion to dryland, yields significant water savings, yet still has a negative impact to the regional economy of -$78.72 per ac-ft of water saved. Changing to more efficient irrigation systems comes with the highest estimated implementation cost of $41.12 per ac-ft of water saved. Conservation tillage is a proven water management strategy that is already widely adopted in the region, however, further adoption would result in significant water savings at the lowest implementation cost per acre-foot. Precipitation enhancement and irrigation scheduling appear to provide the potential of significant water savings while positively impacting the regional economy. However, of all the strategies considered, less documentation of the effectiveness of these two strategies exists.

It is recommended that water conservation strategies selected by the water planning group should go through a more thorough analysis prior to implementation. These analyses should include a more detailed documentation of the selected strategies; a county level assessment of the water savings impacts; and a complete cost analysis of the strategy or strategies including required government expenditures and producer bourn costs. Completing these analyses will allow for development of an implementation plan of action that could maximize water savings given available funding for a specific strategy or combination of strategies on a county and regional basis.

Finally, it would be remiss not to provide the warning that the associated water savings with these strategies are “potential” water savings. In the absence of water use constraints, most if not all the strategies considered will simply increase gross receipts. In fact, the improved water use efficiencies generated from some of these strategies may actually increase the depletion rate of the Ogallala Aquifer.

USING THE NPET TO SCHEDULE IRRIGATION

Dustin Gaskins and DeDe Jones[1]

Strategy: Evaluate the impact of implementing irrigation scheduling through the use of the North Plains Evapotranspiration (NPET) Network. In the Senate Bill 1 report for Region A, this strategy was projected to save two inches of groundwater annually per irrigated acre. Additionally, it should increase water-use efficiency, improve planting decisions, and enhance water-research abilities and associated technologies.

Implementation: In the baseline year of 2000, it's assumed that 20 percent of Region A's irrigated acres employ PET crop water use data. The expectation is that 70 percent of the irrigated acres from 2001 to 2010 and 90 percent from 2011 to 2060 will use PET irrigation recommendations.

Description:

Irrigation of agricultural crops is the largest use of water in the Texas High Plains. Annual crop production receipts in the northern 26 counties of the Texas Panhandle exceed $950 million, and the estimated agribusiness economic impact is more than $3.40 billion (Amosson and Ledbetter, 2000). The Ogallala aquifer is the primary source of irrigation water within this region. However, depletion of the Ogallala by excessive pumping is threatening rural economies. There is a critical need for developing sound water management policies to improve irrigation water utilization and extend the aquifer's life. One strategy recommended in Senate Bill 1 for producers in Region A was to schedule irrigation through the use of the North Plains PET Network. This strategy should increase water-use efficiency, improve irrigation timing, improve planting decisions, and enhance water-researching abilities. However, while the NPET appears to have many benefits, studies have shown that producers are generally unwilling to pay for this technology if an annual fee is imposed. This view stems from the opinion that personnel and program efforts are already being funded by state tax dollars.

The NPET Network is aimed at providing data to improve irrigation scheduling. The network offers a uniform and dependent source of crop water use for both irrigators and the public. PET stands for "potential evapotranspiration," which is the amount of water that a well-irrigated crop uses. The NPET is comprised of 10 meteorological stations in Region A and used to acquire crop weather data focusing on corn, sorghum, cotton, wheat, and soybeans (Comis, 2000). Faxes of the data are sent out each morning at 6:00 a.m. showing daily weather information, including solar radiation, air temperature, relative humidity, wind speed, wind direction, precipitation, and soil temperature. This information is also available electronically on the World-wide Web. The general weather data is then used to compute daily reference evapotranspiration and growing degree days. These computed parameters help farmers know exactly when conditions are optimal to plant and irrigate. This information is especially critical when

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[1] Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106 and Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106.

moisture is short, and when well capacity is limited, as producers must carefully schedule the timing of their applications to efficiently use their water resources (Marek, et al. 1995).

The NPET offers potential regional information as well. The weather stations provide rainfall, soil temperature, climatic data, and water use data not previously representative of agriculturally based conditions. The data allows for the evaluation of sudden weather events like late spring or early fall freezes. The NPET doesn't provide storm warnings, but it provides just about everything else relating to agricultural production, including giving pest alerts. In fact, the summer of 2000 was the first time farmers and consultants woke up to corn rootworm alerts faxed from the network, providing advance notice that an outbreak was imminent (Comis, 2000).

The NPET Network has a wide range of both agricultural and non-agricultural users. Faxes are sent each day to growers, irrigators, crop consultants, and agribusinesses. Faxes are also sent to local newspapers, radio and television stations. For instance, data for lawn water needs is published in the *Amarillo Globe News* each day from May through November. In this publication, crop coefficients are used to estimate daily water use for bluegrass, Bermuda grass, and buffalo grass (Howell, 1998). The NPET is also used extensively by non-profit organizations to improve water research and planning estimates. For example, the Texas' North Plains Underground Water Conservation District recently employed the weather station data to more accurately estimate Ogallala Aquifer depletion (Comis, 2000).

Documentation:

While the NPET Network has many benefits, studies indicate that farmers are generally unwilling to pay for this technology. A 1997 survey by Kenkel and Norris asked Oklahoma growers what they would pay for both raw and refined data from the Oklahoma Mesonet, a larger, statewide network of non-agricultural based weather stations. The aggregate estimates of statewide willingness to pay ranged from $352,488 to $1,949,064 for raw data and from $419,316 to $2,236,368 for refined (value added) data. Based on these estimates, the authors concluded that user fees levied on growers would not pay for Oklahoma Mesonet.

A similar study was conducted by the University of California concerning CIMIS, a network of weather stations run by the California Department of Water Resources. The CIMIS study asked network adopters about their water use and yield benefits from irrigation scheduling with CIMIS information. They were subsequently asked their willingness to pay for that information. A sample of 41 irrigation adopters completed the survey. The sum of lower-bound benefits responses (water savings plus yield increases) was $780,824 and the subsequent question stated willingness to pay of those same producers summed to $20,134. In other words, the sum of lower-bound benefits was 39 times as large as the lower-bound willingness to pay responses. Overall, the data found an average willingness to pay of less than $3 per acre, though irrigation scheduling services in California's Central Valley cost approximately $5-$10 per acre for cotton and other field crops (Cohen and Zilberman, 1997). Considering the comparative value and production of higher end crops in California, this results in a virtual "no pay" response assessment.

A NPET survey conducted in 2000 supported the assertion that producers may be unwilling to pay for irrigation technology in general. Out of 53 responses from producers and consultants, only 52 percent stated they would support an annual fee for NPET data. One explanation for this reluctance is that the same study indicated questionable water savings through the NPET Network utilization. Only 3 out of 12 producers reported a decrease in water applied. These three producers manage 13,000 irrigated acres out of 41,301 total acres (Table 1). Average water saved as reported by the producers was 2.5 inches per acre per summer season crop. Two other producers whose water use remained unchanged reported increases in yield. These producers manage 17,600 acres, and reported an average yield increase valued at $22.50 per acre. The total estimated yield increase value was $396,000 for 17,600 acres.

One response from consultants showed a decrease in water use with an average saving of 1.5 inches per summer season crop. Three responses actually reported an increase in water use, though none of them indicated the water increase quantitatively. Two out of those who reported increased water usage mentioned an increase in yield. These consultants managed 27,920 acres, and reported an average yield increase valued at $54 per acre. The total estimated yield increase value was $1,507,680 for 27,920 acres (Table 2).

Table 1. Irrigated acres reported by NPET survey respondents in the year 2000.

Crop/User Category	Producers	Consultants
Corn	14,036	45,000
Grain Sorghum	4,700	23,500
Peanuts	250	-
Wheat	12,550	30,500
Soybeans	1,040	2,800
Alfalfa	265	1,120
Cotton	8,200	45,000
Other	260	-
Total	**41,301**	**147,920**

Table 2. Amount of irrigation water applied per crop (increased or decreased) as a result of using the NPET to schedule irrigation.

	Producers	Consultants
Increased	0	3
No Change	9	4
Decreased	3	1
If decreased, water saved (in/ac)	3	2
Value of yield increased ($/acre)	$22.50	$54.00
Total Acres affected by yield increase	**17,600**	**27,920**

Baseline Analysis:

In the base year 2000, the approved FSA numbers indicate there were 1,502,159 irrigated acres in the Texas High Plains (Table 3). Long Term Average (LTA) applied irrigation numbers from the Region A Water Use Model show irrigated hay uses the most irrigation water per acre, 31.24 inches per acre. However, more than 50 percent of the 1,756,961 acre-feet of irrigation water used annually in Region A are applied to corn acreage.

Table 3. FSA Acreages and Estimated Applied Irrigation

	2000 Baseline			
	FSA Acreage	**Avg Irr** (inches / acre)	**Total Irr** (Acre-Feet)	**% Applied Irr**
Corn	571,629	18.52	882,152	50.21%
Wheat	643,806	10.39	557,653	31.74%
Sorghum	116,612	9.98	97,012	5.52%
Cotton	37,005	10.69	32,972	1.88%
Soybean	56,661	9.95	46,969	2.67%
Peanut	25,285	17.05	35,927	2.04%
Hay	11,936	31.24	31,069	1.77%
Other	39,225	22.40	73,208	4.17%
Total	**1,502,159**		**1,756,961**	

The original adoption rate contained in Senate Bill 1 was determined to be too aggressive. After consulting with Texas Cooperative Extension Specialists and Texas Agricultural Experiment Station Engineers, it was determined that 10 percent of the irrigated acreage in Region A utilized the NPET Network in the year 2000. Further, it is expected that 20 percent of the irrigated acreage will adopt the use of the PET Network by 2010. An additional 7½ percent of the irrigated acreage in Region A is assumed to employ the network each decade from 2020 until 50 percent of the irrigated acreage has adopted the NPET Network to schedule irrigation in 2050. The level of adoption is held at 50 percent for the remainder of the projection. In addition, the estimated water savings of two inches per acre under Senate Bill 1 was also determined to be excessive. It is assumed that irrigated cropland utilizing the NPET Network will conserve one inch per acre of water.

Results:

Use of the North Plains Evapotranspiration Network has many potential benefits, including increased water-use efficiency, improved planting decisions, and enhanced water-research abilities. While no conclusive evidence exists that suggests use of the NPET Network will generate water savings, surveys conducted in California as well as Region A suggest that producers using this type of data experience gains in production. Assuming that producers would prefer to conserve water rather than increase production, the conclusion can be drawn that improved irrigation scheduling will produce water savings.

The cost of implementing this water conservation strategy is evaluated in terms of the purchase and maintenance of weather stations used throughout the NPET Network. It is assumed that the stations within the network incur maintenance expenses of $125,000 annually. Each weather station is estimated to have a 10-year life expectancy with a total of $100,000 being required each decade for replacements. The total estimated cost incurred by the NPET Network over the planning horizon is $8.1 million. The impact on the regional economy must also be considered when making such substantial changes to the area’s primary source of crop revenue. This impact is measured in terms of the resulting change in gross crop receipts. This analysis assumes that there are no changes in gross crop receipts because producers are willing to take the benefit of improved irrigation scheduling in the form of water savings rather than increased production.

It is assumed that one inch per acre of water is conserved on each acre of irrigated cropland that utilizes the NPET Network to schedule irrigation. Under this assumption, it is estimated that 125,180 acre-feet of water is saved from 2010 – 2019 when an additional 10 percent of the irrigated acreage utilizes the NPET Network to schedule irrigation (Table 3). Total water savings increase by 93,885 acre-feet of water each decade from 2020 – 2050 as 7½ percent of all irrigated acreage in Region A begin using information provided by the network. The total water savings over the 60-year analysis period are estimated to be 2,065,469 acre-feet, or 1.96 percent of the total projected irrigation water use.

The cost of generating water savings must be weighed against the benefit of doing so. To accomplish this, a “price tag” needs to be given to the water that is conserved. It is estimated that the cost of generating each acre-foot of water conserved is $3.92 (Table 4). This number is derived by dividing the cost of implementing this strategy by the amount of water savings generated.

Table 4. Estimated Affected Acreage, Cost of Implementation, Regional Impact, Water Savings, and Cost of Water Savings

	2010	2020	2030	2040	2050	2060	**Total**
Affected Acreage	150,216	262,878	375,540	488,202	600,864	600,864	
Implementation Cost (Millions)	$1.35	$1.35	$1.35	$1.35	$1.35	$1.35	**$8.1**
Regional Impact (Millions)	n/a	n/a	n/a	n/a	n/a	n/a	**$0**
Water Savings (Acre-Feet)	125,180	219,065	312,950	406,835	500,720	500,720	**2,065,469**

Cost of Water Savings Generated ($ per Acre-Foot)

Implementation Cost / Water Savings	$3.92
Regional Impact / Water Savings	$0.00

Summary and Conclusions:

The original assumption of this strategy under Senate Bill 1 was that 20 percent of the irrigated acreage in Region A utilized crop water use information from the NPET Network. 70 percent of the irrigated cropland was expected to begin using this information by 2010 and 90 percent utilizing it from 2011 – 2060. However, it has been determined that this rate of adoption is unrealistic. The updated adoption rate assumes that 10 percent of the irrigated acreage in Region A utilized the NPET Network in the year 2000. Further, it is expected that 20 percent of the irrigated acreage will adopt the use of the PET Network by 2010. An additional 7½ percent of the irrigated acreage in Region A is assumed to employ the network each decade from 2020 until 2050, when 50 percent of the irrigated acreage uses the NPET Network to schedule irrigation. The level of adoption is held at 50 percent for the remainder of the projection. Assuming water savings of one inch per acre, significant amounts of water are conserved, despite the slower rate of adoption. These savings of 2,065,469 acre-feet are equivalent to 1.96 percent of the total projected amount of water that is used to irrigate crops from 2000-2060. The estimated cost of implementation associated with conserving this amount of water is $8.1 million over the 60-year planning horizon.

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CHANGE IN CROP VARIETY

Bridget Guerrero and Fran Bretz[1]

Strategy: Assess the implications of converting from long season corn and sorghum to short season varieties in terms of water savings and regional financial impacts. It is assumed that this change will result in water savings of two inches per acre per year on the affected acreage.

Implementation: In Senate Bill 1, it was assumed in the baseline year of 2000 that 10 percent of the acres were planted to a short season variety of corn and sorghum. Subsequently, it is expected that from 2010 to 2019 and from 2020 to 2060, 40 percent and 70 percent, respectively, of the irrigated acres will be planted to the short season varieties.

Description:

Water conservation is very important to agriculture in the Texas High Plains. Throughout Region A, farmers depend on water to make a living that in turn supports rural economies. Annual crop production receipts in the northern 26 counties of the Texas Panhandle exceed $950 million, and the estimated agribusiness economic impact is more than $3.40 billion (Amosson and Ledbetter, 2000). In experiencing recent drought years, it has become extremely important to investigate different production strategies that will conserve water, yet continue to generate a profit for producers.

One strategy that could potentially help producers conserve water is to change crop varieties from long season corn and sorghum to short season corn and sorghum. This paper analyzes the effects of shifting crop varieties in terms of water savings and regional financial impacts.

Documentation:

In his message to the Congress on July 23, 1953, President Dwight D. Eisenhower declared, "…don't wait for somebody else to tell you what to do in developing adequate plans for proper land use and resource improvement." (The Cross Section, 2004) He went on to say "that conserving and improving our land and water resources is high priority business for us all…" History demonstrates how this once thought of "plentiful resource" of water has slowly been utilized through the years. According to McGuire (2003), the High Plains Aquifer (underlying 174,000 acres in eight states-Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming) irrigated 2.1 million acres in 1949, 13.7 million acres in 1980, and 13.9 million acres in 1997.

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[1] Extension Assistant, Texas Cooperative Extension, Amarillo, TX 79106 and Research Associate, Texas Agricultural Experiment Station, Amarillo, TX 79106.

According to McGuire (2004) from 1950 to 2002, the area-weighted average water level in the aquifer underlying Texas decreased by 34.7 feet. This translates into a decrease in water storage of 124 million acre-feet during this same time period.

Because of the decrease in water availability and a severe drought throughout Texas in 1997, Senate Bill 1 was enacted to determine methods of preserving the finite resource, water. Irrigation accounts for approximately 90 percent (Freese and Nichols, 2001) of the water use in Region A. As a result, the priority for the Agricultural Demands and Projections Subcommittee of the Panhandle Water Planning Group for the 21 counties in Region A was to determine potential water management strategies in production agriculture. Seven water management strategies were selected in Senate Bill 1.

Senate Bill 2 is now underway and further, detailed research is being done on each of these strategies. This analysis will discuss the viability of a change in crop variety. Specifically, this means converting from long season corn and sorghum to short season corn and sorghum.

Howell, Tolk, Schneider, and Evett (1994) indicate there are predominantly three reasons for converting to short season crops. First, there are reduced irrigation requirements because the growing season is shortened. This situation also shifts the growing season a few days to cooler or less arid conditions. Second, a short season hybrid may be seeded earlier to get ahead of a potential insect threat. This is primarily a concern for central and south Texas growers. Third is the option of planting a third crop in two years by planting a short season variety early prior to planting wheat or planting it late following a wheat crop.

A study conducted by Trimmer (1994) indicated that changes in cultural practices can affect the amount of water used. Substituting a shorter-season crop into a rotation appeared to be a viable option for saving water. It was determined that these varieties may not have as much yield potential, but will likely produce a crop. A significant point of this study was to apply one irrigation near a critical-growth stage, such as flowering.

Further analysis indicated that while substituting long season varieties with short season varieties can generate substantial water savings for corn, the result is minimal for sorghum. This is due to the fact that although short season sorghum generally has a shorter growing period than long season sorghum, late planted short season sorghum will remain in the field and continue to slowly mature as long as frost conditions do not occur. Therefore, the short season sorghum uses additional heat units even though the crop has initiated maturity stage development (Marek and New, 2004-personal communication).

Methodology:

This analysis evaluates the implications in terms of water savings and financial impacts of shifting acreage from long season corn and sorghum to short season varieties. The Region A Water Demand Model developed in Senate Bill 2 – Task 2 was a source of data for this analysis. It was used to determine average irrigation water use values for corn and sorghum. Farm Service Agency (FSA) acreages were also utilized, which have been previously approved by the Texas Water Development Board.

The cultural practices to be altered in the analysis are as follows: long season corn acres will be converted to short season corn acres, and long season sorghum acres will be shifted to short season sorghum acres. For both crops, it is assumed in the baseline year of 2000 that 10 percent of the acres were planted to a short season variety. It is expected that from 2010 to 2019 and from 2020 to 2060, 40 percent and 70 percent, respectively, of the irrigated acres will be planted to the short season varieties.

There is virtually no “out of pocket expense” of implementing this water conservation strategy due to the fact that there is no need to purchase any additional equipment or land. However, water savings are generated using this strategy. These water savings are measured in acre-feet. They are calculated by applying the difference in water use between long and short season varieties first to the 2000 baseline FSA acreages. Subsequently, the percentage of water used by short season crops in relation to the total water use of long season crops is multiplied by the change in acreages from 2010 to 2060. As acreage shifts from long season crops to short season crops, water savings result.

Crop evapotranspiration (ET) data were collected for the base year from the North Plains Evapotranspiration (NPET) network for corn located at the Dalhart, Etter, and White Deer stations (Table 1). For sorghum, crop ET data were obtained from the Bushland, Perryton, and White Deer stations. These particular sites were chosen for study because these locations are representative sample sets for corn and sorghum grown in Region A. The planting date used for corn was April 15; whereas, May 15 was the planting date utilized for sorghum. For 2000, short season corn average water use was 78.32 percent of what was required by the long season variety (Table 1). On the other hand, water use was not significantly different between the two sorghum varieties. The short season crop water use averaged 93.58 percent of what was required by the long season variety (Table 1).

Table 1. **Percentage of ET utilized by short season corn and sorghum as compared to long season corn and sorghum (2000).**

Corn		**Sorghum**	
NPET Station Location	**Percent ET for Short Season Corn***	**NPET Station Location**	**Percent ET for Short Season Sorghum***
Etter	79.20%	Bushland	93.23%
Dalhart	78.42%	Perryton	95.17%
White Deer	7 7.34%	White Deer	92.33%
Average % over three weather stations	78.32%	Average % over three weather stations	93.58%

*Source: NPET Network

Yield data used in this analysis were obtained from two sources; 1) actual field demonstration studies (Agri-Partner) conducted within the Texas High Plains by the Texas Cooperative Extension (TCE) irrigation program, and 2) compiled values of the Texas Agricultural Statistics Service (TASS). To ascertain that the field data were representative of the statistical data from TASS, a percentage computation was made regarding the difference between the long and short season production levels for each crop. If the relative field production percentages were similar to the TASS percentages, it could be assumed that the sampling distribution from the TCE Agri-Partner data was representative of the TASS "population" data.

For corn, the high TASS values were chosen to represent the long season production yield, with average selected as the short season production level. The percentage between these two levels were computed and were similar to the percentage calculated between long and short season field production; thus, the statement of representation can be assumed that the Agri-Partner data are comparable to those of the TASS data regarding corn and use of the TASS values is justified in the analysis.

Similarly for grain sorghum, a comparative analysis was attempted. However, due to the lack of representative short season Agri-Partner grain sorghum data, no valid comparison could be readily made to the TASS values as was done with corn. The average production values for the long season grain sorghum appeared to be indicative of known levels experienced within the region (Marek, 2004-personal communication). Nonetheless, TASS grain sorghum data were used, as there was no other known representative data for comparison. Again, long season levels were represented by the TASS high yield values and TASS average grain sorghum values were used as short season grain sorghum production levels.

The regional economic impact of this strategy is measured by the change in gross receipts as acreages are shifted from long season to short season. Gross receipts are calculated by using five-year (1998-2002) average regional crop prices obtained from the Master Marketer website (http://mastermarketer.tamu.edu/), and five-year average high and average yields obtained from the Texas Agricultural Statistics Service (TASS, 1998-

2002). When determining the regional impact of shifting acreage from long season to short season, the high yield was used for long season varieties and the average yield was used for short season crops. These yields were then multiplied by the average prices and the change in acreages for each crop.

The cost of water savings is calculated by comparing the regional economic impact with the water savings produced. When evaluated, the cost to the region of saving an acre-foot of water is calculated by dividing the total regional impact by the total water savings from 2010 to 2060.

Baseline Analysis:

In the base year of 2000, FSA estimated the irrigated corn acreage at 571,629, and the irrigated sorghum acreage at 116,612 (Table 2). Table 2 also includes the five-year (1998-2002) average prices per bushel for corn ($2.29) and per hundredweight for sorghum ($3.70) obtained from the Master Marketer website.

Irrigated corn and sorghum yields in Region A for the base year 2000 were obtained from the Texas Agricultural Statistics Service (TASS) and appear in Table 2. A five-year regional average high yield was calculated for the long season crops and an average yield from 1998-2002 was determined for the short season varieties.

Table 2. **Estimated Yields, Prices, Acreage, and Irrigation for Corn and Sorghum.**

Crop	Yield*	Price*	2000 FSA Acreage	Avg Irr (in/ac)
Long Season Corn	201 Bu	$2.29 / Bu	514,466	18.93
Short Season Corn	170 Bu	$2.29 / Bu	57,163	14.83
Long Season Sorghum	59.94 Cwt	$3.70 / Cwt	104,951	10.05
Short Season Sorghum	45.23 Cwt	$3.70 / Cwt	11,661	9.40

*Average from 1998-2002 for North Region of Texas (Source: TASS and the Master Marketer website - http://mastermarketer.tamu.edu/)

The average water use for corn and sorghum in the Texas High Plains was obtained from the Region A Water Demand Model developed in Senate Bill 2 – Task 2 (Marek, 2004). During 2000, the projected water use was 882,152 acre-feet for corn and 97,012 acre-feet for sorghum. Both long and short season corn and sorghum irrigated water use collectively was projected at 979,164 acre-feet. The average water use for long season corn was estimated at 18.93 inches per acre; whereas, the average water use for the short season variety was 14.83 inches per acre (Table 2); this is a difference of 4.10 inches per acre or 21.66 percent difference in water use between the two crop types. It was also determined that in 2000, long season sorghum utilized 10.05 inches per acre as opposed to the short season variety that used 9.40 inches per acre (Table 2). This is a difference of only .65 inches per acre or 6.47 percent difference in water use between the two sorghum varieties.

Results:

It is anticipated that 586,466 acre-feet of water could be saved from 2010 to 2019 when 40 percent of the total corn acreage is planted to short season corn. From 2020 to 2060, water savings increase to 1,172,932 acre-feet per decade when 70 percent of the total corn acreage is planted to short season corn. The total water savings for corn over the 60-year period is estimated to be 6,451,128 acre-feet (Table 3).

There is an estimation of 18,835 acre-feet saved from 2010 to 2019 when 40 percent of the total sorghum acreage is planted to short season varieties. These water savings increase to 37,669 acre-feet per decade from 2020 to 2060 when 70 percent of the total sorghum acreage is planted to short season sorghum. These water savings are not as significant as those with corn (Table 3). This situation is due to the fact that although short season sorghum generally has a shorter growing period than long season sorghum, late planted short season sorghum will remain in the field and continue to slowly mature as long as frost conditions do not occur. Therefore, the short season sorghum uses additional heat units and water even though the crop has initiated maturity stage development (Marek and New, 2004-personal communication). The total water savings for sorghum over the 60-year period is estimated to be 207,181 acre-feet (Table 3).

***Table 3.* Estimated Affected Acreage, Gross Receipts, Regional Impact, Water Savings, and Cost of Water Savings for Corn and Sorghum.**

Corn

	2010	2020	2030	2040	2050	2060	Total
Affected Acreage	171,489	342,977	342,977	342,977	342,977	342,977	
Regional Impact (Millions)	-$122	-$243	-$243	-$243	-$243	-$243	**-$1,339**
Water Savings (Acre-Feet)	586,466	1,172,932	1,172,932	1,172,932	1,172,932	1,172,932	**6,451,128**

Cost of Water Savings Generated ($ per Acre-Foot)

Regional Impact / Water Savings -$207.58

Sorghum

	2010	2020	2030	2040	2050	2060	Total
Affected Acreage	34,984	69,967	69,967	69,967	69,967	69,967	
Regional Impact (Millions)	-$19	-$38	-$38	-$38	-$38	-$38	**-$209**
Water Savings (Acre-Feet)	18,835	37,669	37,669	37,669	37,669	37,669	**207,181**

Cost of Water Savings Generated ($ per Acre-Foot)

Regional Impact / Water Savings -$1,010.93

When discussing change in crop variety, the impact on the regional economy must also be considered. This is measured by the change in gross receipts. It is anticipated that due to lower crop yields, there will be a reduction in total gross receipts of $122 million in corn from 2010 to 2019 and $243 million every decade thereafter over the planning period. The total estimated regional impact from a change in crop variety in corn is $1.34 billion (Table 3). For sorghum, the regional impact is a reduction in gross receipts of $19 million from 2010 to 2019, and $38 million every decade after that from 2020 to 2060. The total estimated regional impact from a change in crop variety in sorghum is $209 million (Table 3).

Water savings benefits must outweigh the costs for any change in crop variety to be practical. The cost to the region of converting to short season crop varieties is substantial for corn. For each acre-foot of water savings, Region A will experience the effects of a decrease of $207.58 in gross receipts (Table 3). The effect from converting to short season sorghum is even greater as gross receipts will decrease a total of $1,010.93 per acre-foot of water saved (Table 3). The regional cost of water savings generated for sorghum is higher because the water savings from converting from long season sorghum to short season sorghum is minimal.

Summary and Conclusions:

During Senate Bill 1, the initial assumptions drawn regarding a change in crop variety for corn and sorghum in Region A were as follows: (1) when converting from long season corn and sorghum to short season crops, it was assumed in the baseline year of 2000 that 10 percent of the acres were planted to a short season variety of corn and sorghum, (2) from 2010 to 2019, 40 percent of long season varieties of corn and sorghum will be planted to short season crops, (3) from 2020 to 2060, 70 percent of the irrigated acres will be planted to the short season varieties, and (4) it is assumed that this change will result in water savings of two inches per acre per year on the affected acreage.

On the average, converting from long season corn to short season varieties results in water savings of 4.10 inches per acre. Conversely, the outcome of switching from long season sorghum to short season sorghum is water savings of .65 inches per acre on average.

Changing from long season varieties to short season varieties will result in significant water savings for corn. By converting only the irrigated corn acres, total water savings would be 6,451,128 acre-feet over the 60-year planning horizon. These savings are 6.12 percent of the total projected amount of water used to irrigate crops within Region A from 2000 to 2060. The cost of the water savings is a $1.34 billion reduction in gross receipts over 60 years.

While substituting long season varieties with short season varieties can generate substantial water savings for corn, the result is comparatively minimal for sorghum. By switching from long season sorghum to short season sorghum, a total of 207,181 acre-feet of water savings result over the 60-year period. These savings equal only .20 percent of the total projected amount of water used to irrigate crops within Region A from 2000 to 2060. The cost of the water savings is quite high with a reduction in gross receipts of $209 million from 2000 to 2060.

Collectively, converting both corn and sorghum from the long season varieties to the short season varieties could generate water savings of 6,658,309 acre-feet over the

60-year period. This equals to 6.32 percent of the total projected amount of water used to irrigate crops in Region A from 2000 to 2060. The combined cost of the water savings is a $1.55 billion reduction in gross receipts over the 60-year planning period.

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IRRIGATION EQUIPMENT CHANGES

Nick Simpson and Dustin Gaskins[1]

Strategy: Evaluate the potential water savings and economic implications of a producer converting to more efficient types of irrigation equipment.

Implementation: It was assumed in Senate Bill 1 that 55 percent of the irrigated acres were utilizing more efficient distribution systems in the baseline year of 2000. It was anticipated that by 2010 an additional 20 percent of the farming/ranching operations would utilize more efficient methods such as surge flow, LESA and LEPA. It was anticipated that 95 percent of the irrigated crops would utilize these irrigation methods by 2050. It was also assumed that 5 percent of the furrow-irrigated acres will be converted to subsurface drip irrigation by 2010. Subsurface drip utilization was assumed to increase to 10 percent and 15 percent by 2020 and 2030, respectively.

Description & Documentation:

The incorporation of more efficient irrigation equipment and technology in a farming/ranching operation provides a method of groundwater conservation. Specific problems associated with irrigation are water wasted by evaporation and runoff and leeching nutrients below the root zone. Current irrigation methods within the region include conventional furrow irrigation (CF), surge flow (SF), center pivot irrigation (MESA - Mid-Elevation Spray Application, LESA - Low Elevation Spray Application, LEPA - Low Elevation Precision Application) and subsurface drip irrigation (SDI). Switching systems can entail a considerable price tag but can also increase the producer’s bottom line by decreasing pumping costs while increasing convenience.

Definitions of the different methods of irrigation are needed to understand this unique strategy. Amosson, et al. (2001) provide the following descriptions. Conventional furrow is a means of irrigation by laying poly or metal pipe on the ground and pumping water through “gates” which are lined up with the field’s furrows. Surge flow is similar to conventional furrow with the exception of a surge valve, which intermittently applies water to two areas of the field. This surge flow concept increases application efficiency by 15 percent. Subsurface drip irrigation (SDI) is the most efficient, in terms of water placement, of all the irrigation systems. SDI is a process of delivering precise amounts of water and nutrients directly to the plant’s root zone. A flat tape or hose is placed in a subsurface manner, thus minimizing surface evaporation losses. The most widely used irrigation system is the center pivot. Center pivot irrigation is allocated to three different systems; Mid-Elevation Spray Application (MESA), Low Elevation Spray Application (LESA), and Low Energy Precision Application (LEPA). New and Fipps (2000) describe MESA as an irrigation system in which water applicators are located halfway between the soil surface and the main line. LESA is defined by utilizing water applicators located only 12-18 inches above the soil.

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[1] Former Research Assistant, Texas Agricultural Experiment Station, Amarillo, TX 79106 and Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106.

LESA can be converted to LEPA with either an attached drag sock or hose. LEPA utilizes either bubble applicators twelve to eighteen inches off the soil surface or a drag sock or hose that directly releases water to the surface.

Each irrigation system can have a different level and range of efficiency and can be dramatically affected by operator management during the growing season. A study by Amosson et al. (2001), estimated conventional furrow, surge flow, MESA, LESA, LEPA and drip with application efficiencies of 60 percent, 70 percent, 78 percent, 88 percent, 95 percent and 97 percent respectively. These application efficiencies are the percentage of irrigation water that is actually used by the crop, while the rest is lost to runoff, evaporation or deep percolation.

Methodology:

The methodology developed for this analysis evaluates the impact of switching to irrigation systems that apply water more efficiently. The impact is measured in terms of water savings, cost of implementation and cost of water savings generated. The primary source of data for this analysis is the Region A Water Demand Model that was developed in Senate Bill 2 – Task 2. This analysis model uses Farm Service Agency (FSA) acreages that have been previously approved by the Texas Water Development Board.

Water savings were calculated based on a combination of an application efficiency index (Amosson et al. 2001) and adopted FSA acres. To calculate water savings from the implementation of this strategy, the proposed changes in irrigation systems are made to the approved FSA acreages. These acreages are then multiplied by average water use per system and added together to derive the total water used per system and scenario.

To determine the costs of implementation, the six different irrigation systems are compared at a marginal tax rate of 15 percent and field coverage of 160 acres (quarter-mile pivot). The costs for the well, pump and engine are assumed to be the same for each system and therefore they are not included in the investment costs. The per-acre cost of each system is illustrated in Table 1 (Amosson et al. 2001). Replacement costs for LEPA and SDI systems and replacement costs for sprinkler heads for LEPA, which is titled reinvestment costs for this strategy, were also added to the cost of implementation. The useful life of each system is 25 years and sprinkler heads have a useful life of eight years (Amosson et al. 2001). At the end of the appropriate system's useful life the replacement cost is then added to the beginning cost of implementation to calculate total implementation costs. Replacement costs for each system is assumed to equal the implementation cost. The replacement cost for sprinkler heads per system is $6,000 per system (Amosson et al. 2001).

Table 1. Net investment costs of irrigation systems.

System	Net Investment ($/acre)
Conventional furrow (CF)	152.63
Surge flow (SF)	171.11
Mid-elevation spray application (MESA)	252.37
Low elevation spray application (LESA)	268.05
Low energy precision application (LEPA)	277.73
Subsurface drip irrigation (SDI)	614.71

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Baseline Analysis:

FSA data for the year of 2000 were chosen to determine total irrigated acres for Region A. However, FSA data does not have irrigated acreage by system and therefore, the Texas Water Development Board Report 347 was used to determine the percentage of furrow and sprinkler irrigated acres. Total irrigated acreage for the baseline year of 2000 totals 1,502,159 (FSA).

As the price of center pivots and drip start to decrease, more producers will shift their less efficient, labor-intensive methods to the more efficient systems. The following changes to the original 2000 baseline and implementation schedule were made in consultation with the Texas Cooperative Extension irrigation specialists; CF 17 percent, SF 2 percent, MESA 2.50 percent, LESA 60 percent, LEPA 18 percent, and SDI 0.50 percent. The less efficient methods of CF, SF and MESA are expected to decrease 2 percent, .25 percent and .25 percent respectively each decade. Gains in acreage by LEPA and SDI will offset this 2.50 percent decrease. LEPA is expected to increase 2 percent every decade totaling 30 percent of all irrigated acres in 2060. SDI is expected to increase 0.50 percent per decade and total 3.50 percent in 2060. LESA is expected to remain constant throughout the periods at 60 percent. It is assumed that the acreage converted from the less efficient systems to LESA will equal the amount changed from LESA to LEPA. Percentages of each system are presented by decade in Table 2.

Table 2. Projected percentages of total irrigated acreage of each system per decade.

	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
CF	17.00%	15.00%	13.00%	11.00%	9.00%	7.00%	5.00%
SF	2.00%	1.75%	1.50%	1.25%	1.00%	0.75%	0.50%
MESA	2.50%	2.25%	2.00%	1.75%	1.50%	1.25%	1.00%
LESA	60.00%	60.00%	60.00%	60.00%	60.00%	60.00%	60.00%
LEPA	18.00%	20.00%	22.00%	24.00%	26.00%	28.00%	30.00%
SDI	0.50%	1.00%	1.50%	2.00%	2.50%	3.00%	3.50%

Results:

The results of making the proposed changes are measured by three means: acreage affected, costs of implementation and water savings.

The baseline acreage of 1,502,159 was adopted from the FSA. Of these 1.5 million acres, 2.5 percent (37,554 acres) are expected to be affected by the implementation of this strategy each decade. The total affected acreage over the 60-year period is 225,324 acres (Table 3).

The estimated cost of implementation for converting irrigation systems is composed of two factors, the initial investment and the replacement costs. The estimated initial investment totals $12,960,853 per decade. The reinvestment costs consist of the 25-year useful life of each system and an eight-year useful life for sprinkler heads. The cost to replace sprinkler heads over an eight-year period is $1,126,619. The 60-year total implementation cost is $169,608,241 (Table 3).

The projected water savings for each system by decade are presented in Table 3 in acre-feet. The increase in water applied through SDI and LEPA reflects the increase in acreage for each of these systems. The transition of these acres from less efficient to more efficient systems accounts for a 196,400 acre-foot water savings from 2000 to 2010. Water savings then increases in 196,400 acre-foot increments each decade throughout the 60-year planning period to total 4,124,398 acre-feet.

The final results of implementing the proposed acreage changes are presented in Table 4. The cost of implementation is based on a 2 percent increase in the purchase of LEPA systems and 0.5 percent increase in SDI. To put a dollar value on the amount of water that is saved, cost of water savings generated is calculated by dividing the implementation cost by water savings. The cost of saving one acre-foot of water for this strategy is $41.12.

Table 3. Estimated system water savings per decade.

	System Water Use Per Decade						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
CF	4,090,028	3,608,849	3,127,669	2,646,489	2,165,309	1,684,129	1,202,950
SF	382,980	335,107	287,235	239,362	191,490	143,617	95,745
MESA	462,358	416,122	369,887	323,651	277,415	231,179	184,943
LESA	9,819,996	9,819,996	9,819,996	9,819,996	9,819,996	9,819,996	9,819,996
LEPA	2,739,779	3,044,199	3,348,619	3,653,039	3,957,458	4,261,878	4,566,298
SDI	74,468	148,937	223,405	297,873	372,342	446,810	521,278
Total Irrigation (acre-feet)	17,569,610	17,373,210	17,176,810	16,980,410	16,784,010	16,587,610	16,391,210
Savings		196,400	392,800	589,200	785,600	982,000	1,178,400
Total water savings (acre-feet)							**4,124,398**

Table 4. Results of implementing system changes from 2010 through 2060.

	2010	2020	2030	2040	2050	2060	60-Year Total
Acreage Affected	37,554	37,554	37,554	37,554	37,554	37,554	225,324
Initial Investment	$12,960,853	$12,960,853	$12,960,853	$12,960,853	$12,960,853	$12,960,853	$77,765,119
Reinvestment	$1,126,619	$2,253,238	$16,340,710	$18,593,948	$19,720,567	$33,808,039	$91,843,122
Total Implementation	$14,087,472	$15,214,091	$29,301,563	$31,554,801	$32,681,420	$46,768,893	$169,608,241
Water Savings	196,400	392,800	589,200	785,600	982,000	1,178,400	4,124,398
	Cost of Water Savings Generated ($ per Acre-Foot) Implementation Cost / Water Savings						$41.12

Summary and Conclusions:

It is assumed that by the end of the planning period conventional furrow would decrease by 2 percent and LEPA would increase by 2 percent each decade throughout the 60-year planning period. LESA's percentage of the total irrigated acres is expected to stay constant at 60 percent. Surge flow and MESA are expected to each decrease by 0.25 percent while sub-surface drip is expected to increase 0.50 percent per decade over the 60-year horizon. The changes in irrigation systems account for a total water savings of 4,124,398 acre-feet. The water savings generated are expected to cost $169,608,241 in implementation costs. This equates to a cost of $41.12 per acre-foot of water conserved. The total water savings (4,124,398 acre-feet) is 3.91 percent of the total water used.

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CHANGE IN CROP TYPE

Dustin Gaskins[1]

Strategy: Analyze the impact of shifting irrigated planted acreage from high water use crops to types of crops that require reduced amounts of applied irrigation. The cost of water savings associated with this shift is calculated using the change in gross receipts.

Implementation: It is assumed that 20 percent of the irrigated corn acreage in Region A will be shifted to equal amounts of irrigated sorghum, soybean, and cotton in 2010, with 40 percent being converted by 2020. No additional changes are assumed to occur beyond 2020. Furthermore, it is assumed irrigated soybean and sorghum acreage will be converted to irrigated wheat at the same rate.

Description:

Water conservation has become a very important concern regarding Texas agriculture. This holds especially true in the High Plains region where irrigation is a necessity due to a lack of adequate rainfall. Large amounts of water are applied each year by production operations to supplement the relatively low amount of annual rainfall and produce high yields of quality products. As the overall water table in the Ogallala aquifer continues to decline, producers must evaluate alternative management strategies that will enable them to cope with the reduced availability of groundwater to be used for irrigation.

One method of reducing the amount of groundwater used for irrigation is changing the type of crop that is planted. This strategy involves shifting acreage from the high water use crops currently produced to a type of crop with lower water use requirements. To date, the majority of water used for irrigation has been applied to high water use crops such as corn. This paper will analyze the impact of this crop shift in terms of water conserved (in acre-feet) and the financial cost of implementation on a per acre basis.

Documentation:

The declining water level in the Ogallala aquifer has been documented in many studies. The High Plains Underground Water Conservation District No. 1 estimates that 95 percent of the water pumped from the aquifer is used for irrigation and that the High Plains region accounts for 65 percent of the total irrigation acreage in the United States. Most of the region is semi-arid and experiences high evapotranspiration rates. Water levels in the aquifer's southern High Plains declined through the 1950s, 1960s, and 1970s and then began to stabilize. However, from 1992 through 1997 it is estimated that the aquifer declined at an average rate of 1.35 feet per year due to drought conditions.

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[1] Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106.

Arabiyat, Segarra, and Willis (1999) indicate that most of the water used for irrigation in the U.S. is obtained from groundwater supplies. Fourteen million irrigated acres are located in areas where groundwater aquifers are declining. Four of the fourteen million irrigated acres are situated in Texas. The majority of this Texas acreage can be found in the Texas High Plains (THP) where the primary source of irrigation water is the Ogallala aquifer. Overdraft over the last three decades has caused a significant reduction in the aquifer's saturated thickness and an increase in pumping lift. Furthermore, it has been estimated that 30 percent to 35 percent of the pre-development groundwater resources in the Texas High Plains have been mined.

The Texas Water Development Board estimated in 1995 irrigation of crops accounted for 65 percent of the total water use in Texas. Four crops in the state accounted for almost 75 percent of the irrigated cropland in 1994 and 85 percent of the water usage. Several studies have been conducted in the High Plains region to illustrate the amount of water required by the varying crops grown in the area. Howell, et al, (1996) indicated that corn has one of highest water requirement of any irrigated crop grown in the THP because of a longer growing season than most other spring crops and adverse affects on yield in limited moisture situations. Sorghum was found to require less irrigation water due to lower evapotranspiration (ET) rates than both corn and winter wheat (Howell, et al 1997). Wheat was shown to have an even higher ET rate than corn due primarily to an even longer growing season than corn and diverse weather conditions. However, less irrigation water is used for winter wheat because it is dormant for part of the growing season and requires less moisture during this period. Wheat is also rarely fully irrigate because it responds well to limited water conditions.

Methodology:

This analysis evaluates the impact of shifting acreage from higher water use crops to crops that require less moisture. This impact is measured in terms of cost of implementation, water savings, regional economic impacts, and cost of water savings generated. The primary source of data for this analysis is the Region A Water Demand Model that was developed in Senate Bill 2 – Task 2. This model uses Farm Service Agency (FSA) acreages that have been previously approved by the Texas Water Development Board. Average water use figures for the five irrigated crops prevalent in the THP (corn, sorghum, soybean, cotton, and wheat) were also obtained from the model.

The cost of implementing this water conservation strategy is evaluated in terms of reduced land values. It is assumed the reason land is being shifted away from corn production is to generate water savings. Land that has more water available for irrigation is worth a premium compared to land with limited irrigation resources. Therefore, as land is shifted from corn to lower water use crops, its value is reduced.

Water savings generated by this strategy are measured in acre-feet. These savings are calculated by first making the proposed changes to the baseline FSA acreages. The adjusted acreage is then multiplied by the corresponding crop's average water use number. As acreage shifts from the higher water use crops to crops that require less moisture, water savings are generated.

The regional economic impact of this strategy is analyzed in terms of the change in gross receipts on the affected acreage. Gross receipts are calculated by using a five-year (1998-2002) average regional price and yield. The prices were obtained from the Master Marketer Program and the Texas Agricultural Statistics Service (TASS), while yields were acquired from TASS. These regional average yields and prices were then multiplied by the corresponding amount of the planted acreage for each crop.

The cost of water savings is evaluated in two ways. The first, gives an indication of the cost incurred by producers to generate an acre-foot of water savings. This measure is generated by dividing the total change in land values by the amount of water conserved. The second method of estimating the water savings cost, evaluates the cost to the region of saving an acre-foot of water. This estimate is calculated by dividing the change in gross revenues by the total water savings.

Baseline Analysis:

In the base year, 2000, the approved FSA numbers indicate there were 1,425,713 acres planted to the five prevalent irrigated crops in the High Plains region (Table 1). Also presented in Table 1 are the five-year (1998-2002) yields and prices for each crop. Long Term Average (LTA) applied irrigation numbers obtained from the Region A Water Use Model show that 55 percent, or 882,152 acre-feet, of the total irrigation water applied to the five major crops in Region A (Table 2) is applied to corn, which accounts for only 40 percent of the irrigated acreage.

The following changes in acreage are assumed: corn acres are converted to sorghum, cotton, or soybean acres in equal proportions. From the 2000 baseline year until 2009, it is assumed that none of the acres undergo a shift in the type of crop planted. It is expected that 20 percent of the acreage changes crop type from 2010 to 2019, and that a total of 40 percent changes from 2020 to 2060. No acreage is assumed to be converted from soybean and sorghum to wheat, as was proposed in Senate Bill 1, because the revised Senate Bill 2 LTA water use numbers by crop indicate this change does not generate any water savings. This is due to a higher ET rate, longer growing season, and the feasibility of applying full ET irrigation levels.

Table 1. Estimated Yields, Prices, and Acreage for Irrigated Panhandle Crops			
	2000 FSA Acreage	**Yield***	**Price***
Corn	571,629	170.00 Bu	$2.29 / Bu
Wheat	643,806	46.28 Bu	$2.70 / Bu
Sorghum	116,612	45.23 Cwt	$3.70 / Cwt
Cotton	37,005	630.00 Lbs	$0.45 / Lb
Cotton Seed	37,005	0.53 Tons	$102.00 / Ton
Soybean	56,661	40.54 Bu	$4.26 / Bu
Total	**1,425,713**		
* Average from 1998-2002 for North Region (Source: TASS and MM)			

Table 2. Amount of Irrigation Water Applied by Crop in 2000						
	Corn	Sorghum	Soybean	Cotton	Wheat	**Total Irr** (acre-feet)
Avg Irr (inches / acre)	18.52	9.98	9.95	10.69	10.39	
Total Irr (acre-feet)	882,152	97,012	46,969	32,972	557,653	**1,616,757**
% Total Applied Irr	55%	6%	3%	2%	34%	

Results:

Land that has access to sufficient groundwater for irrigating high water use crops such as corn sells for a premium in the Texas High Plains. The Real Estate Center at Texas A&M University estimates the value of such land at $800 per acre. Land with access to marginal ground water that can be used for irrigating crops is estimated at $600 per acre. As cropland is shifted from corn to lower water use crops, it experiences a $200 per acre reduction in value. From 2010 –2019, 114,326 acres are anticipated to undergo such a shift resulting in a loss in value of approximately $23 million (Table 3). The value of land in Region A is reduced by another $23 million from 2020 – 2060 when an additional 20 percent of the irrigated corn acreage is assumed to be planted to soybean, sorghum, and cotton.

It is estimated that 791,818 acre-feet of water is saved from 2010 – 2019 by converting 20 percent of the irrigated corn acreage to soybean, sorghum, and cotton (Table 3). Total water savings increase to 1,583,635 acre-feet of water per decade from 2020 – 2060 when 40 percent of all irrigated corn acreage in Region A is shifted to alternate lower, water use crops. The total water savings over the 60-year analysis period are estimated to be 8,709,995 acre-feet, or 8.26 percent of the total projected irrigation water use.

The impact on the regional economy must be considered when looking at making such substantial changes to the area’s primary source of crop revenue. This impact is measured in terms of the resulting change in gross crop receipts. This measure is used as input into socio-economic model such as IMPLAN to estimate the total impact on the regional economy. It is estimated that Region A experiences an annual reduction in gross revenues of $18.7 million from 2010 – 2019 (Table 3) with a 20 percent reduction in corn acreage. Furthermore, a $37.4 million annual reduction in gross receipts is experienced from 2020 – 2060. Thus, the non-discounted total reduction in gross receipts is $2.05 billion over the 60-year planning horizon.

The cost of generating water savings must be weighed against the benefit of doing so. To accomplish this, a "price tag" needs to be given to the water that is conserved. It is estimated that the cost of generating each acre-foot of water conserved is $5.25 (Table 3). However, the cost to the regional economy is much higher. It is estimated that for each acre-foot of water saved the economy in Region A will experience a $235.85 loss in gross revenue.

Table 3. Estimated Affected Acreage, Cost of Implementation, Regional Impact, Water Savings, and Cost of Water Savings

	2010	2020	2030	2040	2050	2060	**Total**
Affected Acreage	114,326	228,652	228,652	228,652	228,652	228,652	
Implementation Cost (Millions)	$23	$23					**$46**
Regional Impact (Millions)	-$187	-$374	-$374	-$374	-$374	-$374	**-$2,054**
Water Savings (Acre-Feet)	791,818	1,583,635	1,583,635	1,583,635	1,583,635	1,583,635	**8,709,995**

Cost of Water Savings Generated ($ per Acre-Foot)

Implementation Cost / Water Savings	$5.25
Regional Impact / Water Savings	-$235.85

Summary and Conclusions:

The original assumptions of this strategy under Senate Bill 1 were that 20 percent of the irrigated corn acreage in Region A will be shifted to equal amounts of irrigated sorghum, soybean, and cotton in 2010, with 40 percent being converted by 2020 respectively. No additional changes were assumed to occur beyond 2020. Furthermore, it was assumed that similar amounts of irrigated soybean and sorghum acreage would be converted to irrigated wheat. However, it has been shown that no water savings are generated by converting soybean and sorghum acreage to irrigated wheat due to its long growing season and high ET rate. With this assumption omitted, converting irrigated corn acreage to an equal split of irrigated cotton, sorghum, and soybean acreage still results in significant water savings. These savings of 8,709,995 acre-feet, are equivalent to 8.26 percent of the total projected amount of water that is used to irrigate crops from 2000-2060. The estimated cost of conserving this amount of water is $46 million in implementation costs. Accordingly, $2.05 billion in gross revenue is estimated to be lost over the 60-year planning horizon if the implementation is carried out.

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CONSERVATION TILLAGE

Nick Simpson[1]

Strategy: Evaluate the impact of converting irrigated acreage from a conventional tillage practice to a conservation tillage practice to assess any potential irrigation water savings. In Senate Bill 1, it was assumed that two inches per acre of water could be saved per acre that was converted.

Implementation: It was assumed in Senate Bill 1 that in 2000, 50 percent of all irrigated acres utilized conservation tillage. It was also anticipated that 60 percent of the acres would utilize conservation tillage by the year 2010 and increase utilization 70 percent each decade from 2030 through the year 2050.

Description:

Conservation tillage has the potential to be a plausible water management strategy. Conventional disk tillage practices involve approximately six trips over a field each growing season, excluding pesticide and herbicide management trips. This conventional, cultural practice causes considerable amounts of water to be lost from cropland due to evaporation from each tillage operation. Additionally, up to sixty percent of the average annual rainfall in the region is lost to evaporation during fallow periods (Bertrand 1966). Conservation tillage leaves plant residue on the soil surface to help reduce this evaporation loss and to aid in the infiltration of water into the soil where rain and irrigation occurs. Conservation tillage can not only save water, but it may have other benefits. Other benefits that are rarely analyzed from an economic standpoint are the environmental impacts such as topsoil protection, protection of water, such as less chemical runoff into water sources, more nutrient rich soil, and less carbon dioxide released into the air.

Documentation:

A definition of conservation tillage is needed to understand the different terms and scope of this strategy. Towery and Fawcett of the Conservation Technology Information Center (CTIC) give clear descriptions to conservation tillage and different types of conservation tillage according to the amount of crop residue that is left on the surface and the types of tillage tools used. *Conservation tillage* is defined as any tillage and planting system that covers more than 30 percent of the soil surface with crop residue after planting to reduce soil erosion by water. Where soil erosion by wind is the primary concern, any system that maintains at least 1,000 pounds per acre of flat, small grain residue equivalent on the surface throughout the critical wind erosion period is considered to be conservation tillage. Reduced tillage, which will be included under conservation tillage, is defined as a tillage type that leaves fifteen to thirty percent residue cover after planting or 500 to 1,000 pounds per acre of small grain residue after the

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[1] Former Research Assistant, Texas Agricultural Experiment Station, Amarillo, TX 79106.

operation. Conventional tillage is defined as leaving less than fifteen percent residue cover after planting. It typically involves plowing or other forms of intensive tillage.

Conservation tillage is further categorized as no-till, ridge-till, and mulch-till. No-till leaves the soil undisturbed from harvest to planting. Ridge-till leaves the soil undisturbed from harvest to planting with the exception of nutrient injection. In ridge-till practices, planting is done in seedbeds prepared on ridges while residue is left on the surface between the ridges. Mulch-till requires disturbing the soil prior to planting, and weeds are controlled with herbicides or mechanical cultivation as they are in the two previous methods. They also discuss the additional benefits of conservation tillage, such as reduced erosion, healthier soil, benefits to wildlife, and less air pollution, including the release of carbon dioxide.

Many studies have documented the water saving characteristics of conservation tillage as well as the importance of available water at planting. Johnson (1964), Jones and Hauser (1975) stated that winter wheat, grain sorghum, and sunflower yields increased 6.42, 15.17 and 6.24 lbs/ac, respectively, for each additional millimeter of plant-available water in Pullman soil at planting time. A study conducted by Unger (1984) evaluated the effects different tillage methods and plant residue levels had on soil water content. Comparing moldboard, disk, rotary, sweep, and no-tillage treatments, he showed that soil water content increased during a fallow period following wheat averaged 3.50, 4.29, 3.35, 4.49, and 5.55 inches for the respective tillage treatments and averaged 3.82 and 4.65 inches for low and high residue treatments. He also stated that sorghum grain yields averaged 41, 38, 35, 44 and 53 bu/ac with the respective tillage treatments. A similar study by Wiese, et al., published in 1998 evaluated the plant available soil water in a four-foot profile at planting of sorghum. After averaging five years of data, no-till had 5.72 inches while conventional tillage had 4.96 inches of plant available water at planting.

For a farmer to accept the idea of conservation tillage, it must be an economically viable endeavor. Several analyses have been performed on conservation tillage. Larry D. Sanders (2002) refers to studies on conservation tillage in the southeastern U.S. that generally suggested that there was little difference in yield or net revenue in the first years of establishment, but over a longer time period the net revenue increased. In a short period of time, the increased soil moisture and nutrients in the soil due to decreased tillage will show an increase in profits as well. Another study by Livingston, et al., (2001) performed on cotton and sorghum in Refugio County, Texas showed lower yields of both crops with conservation tillage but higher returns over variable costs than conventional tillage. This suggests that an increase in production is not needed to maximize profits if the operation can decrease costs. Another study in Lubbock, TX by Keeling, et al. (1987) comparing conventional and conservation tillage of irrigated and dryland cotton showed irrigated conservation tillage cotton generated net returns four percent greater than conventional and dryland net returns twenty-six percent greater. A study conducted by Jones and Johnson (1996) evaluated ten years of conservation tillage. Jones and Johnson illustrate the profitability of conservation tillage over a ten-year period. This is a comprehensive study that compares continuous cropping and a wheat-sorghum-fallow rotation that utilizes the different conservation tillage methods of no-till and stubble mulch tillage. During this period however, half the years in the study experienced significantly above average rainfall.

Methodology:

This analysis evaluates the impact of shifting conventionally tilled acres to conservation tillage. The impact is measured in terms of affected acreage, water savings and estimated cost of implementation. The primary source of data for this analysis was 2000 FSA (Farm Service Agency) irrigated acreage data.

It is assumed that from 2000 to 2010 there will be a 10 percent increase in acreage utilizing conservation tillage. From 2010 to the end of the planning period, acreage in conservation tillage is expected to increase 2.5 percent each decade.

A water savings of 1.75 inches per acre was estimated from shifting an acre of conventional to some form of conservation tillage employing a Delphi approach. Several professionals in different disciplines estimated that as little as 1.50 inches per acre and as much as 2.00 inches per acre could be conserved with the conversion to conservation tillage. The 1.75 inches per acre conserved was slightly lower than what was used in the Senate Bill 1 effort (2.00 inches per acre).

An acre of conservation tillage incurs different levels of cost than an acre of conventional tillage does. The following economic comparison is an estimate of the necessary changes in costs for the respective systems in continuous grain sorghum production. This comparison takes into consideration that all other costs are the same between the two tillage systems and that yield will be equal. The proposed 1.75 inches of water saved per acre are included as additional irrigation costs to conventional tillage, which were derived from the Texas Cooperative Extension publication, *Economics of Irrigation Systems*. The costs, excluding irrigation, come from the Texas Cooperative Extension's 2004 projected crop and livestock budgets and *1999 Texas Custom Rate Statistics*, which are presented below in Table 1.

Table 1. Comparison of variable costs of conventional and minimum tillage systems.

Estimated Costs of Implementation Per Acre		
Expenses	**Tillage System**	
	Conventional	Conservation
Plowing	$29.06	$17.18
Herbicide & Application	$7.85	$31.40
Total	$36.91	$48.58
Added costs from additional 1.75 acre-inches of irrigation	$10.92	$0.00
Total	**$47.83**	**$48.58**

Sources: 1999 Texas Custom Rates Statistics – USDA/NASS; Economics of Irrigation Systems – Texas Cooperative Extension

It is assumed that the average conventionally tilled field will be disked once, chiseled once and cultivated three times during the year with tillage costs totaling $29.06/acre. There is one estimated herbicide application, which is estimated to cost $7.85/acre. Plowing and herbicide costs for conventional tillage total $36.91/acre. It is assumed that conservation tillage will incur two field cultivations and one chiseling which will total $17.18/acre. Also, there are expected to be four herbicide applications totaling $31.40. Total plowing and herbicide expenses are estimated at $48.58. This estimates additional costs for conservation tillage at $11.67 when compared to conventional tillage costs. However, this difference is narrowed when the costs of additional irrigation are added in. The additional 1.75 inches of water applied per acre to conventional tillage is estimated to cost $10.92/acre. After this is taken into account the total implementation costs are $47.83 for conventional tillage and $48.58 for conservation tillage. The final implementation cost is determined by subtracting the total implementation cost of conventional tillage from conservation tillage. This produces an additional $0.75 in implementation costs fro conservation tillage. This $0.75 is then multiplied by the affected acreage for the corresponding decade

Baseline Analysis:

FSA data for the year 2000 was adopted for use by the Region A planning group as baseline acreage. In 2000 FSA reported 1,502,159 irrigated acres in Region A. According to the Conservation Technology and Information Center (CTIC) at Purdue University approximately 50 percent of these acres were utilizing conservation tillage, confirming what was assumed in Senate Bill 1.

The following changes in acreage are assumed: 60 percent of all irrigated acres are in conservation tillage by 2010 and then are assumed to increase by 2.5 percent each decade thereafter, reaching a total of a 72.5 percent by 2060. This adoption scenario is identical to what was used in Senate Bill 1 except for extending the adoption rate out another decade resulting in an additional 2.5 percent adoption of conservation tillage practice.

Results:

The results of converting to conservation tillage are measured using three factors, acreage affected, implementation costs and water savings.

150,216 acres of conventional tillage were converted to conservation tillage in the decade of 2000 to 2010. After this point, the conversion of the acreage increases 2.5 percent (37,554 acres) every decade through 2060. These increases for the 60-year planning period estimate conservation tillage at 72.5 percent (1,089,065 acres) of the current total irrigated acres.

It is estimated that 219,065 acre-feet of water is saved from 2010-2019 by converting 10 percent of conventional tillage acreage to conservation tillage acreage.

Water savings are then expected to increase an additional 54,766 acre-feet per decade as an additional 2.5 percent of the acreage is shifted to conservation tillage. The total water savings over the 60-year analysis period is estimated to be 2,135,882 acre-feet.

This water savings does not come without a cost. A monetary value needs to be assigned to the water that is saved. Converting the 150,216 acres in 2010 will have implementation costs of $112,662 for the region. The 2.5 percent increase in acreage per decade will result in a $28,165 increase in implementation costs each decade, which brings the total implementation cost for the 60-year planning period to $1,098,454. The estimated cost of generating one acre-foot of water conserved is $0.51.

Table 2. Estimated acreage affected, implementation costs, water savings and cost of water savings generated.

	2010	2020	2030	2040	2050	2060	Total
Acreage Affected	150,216	187,770	225,324	262,878	300,432	337,986	
Implementation Costs	$112,662	$140,827	$168,993	$197,158	$225,324	$253,489	$1,098,454
Water Savings	219,065	273,831	328,597	383,363	438,130	492,896	2,135,882

Cost of Water Savings Generated ($ per Acre-Foot)
Implementation Cost / Water Savings **$0.51**

Summary and Conclusions:

The original assumptions of this strategy under Senate Bill 1 were that 10 percent of conventionally tilled irrigated acres would be shifted to conservation tillage by 2010. From 2011 to 2050, each decade would increase conservation tillage by 2.5 percent. No changes were needed in this area. It was also assumed that converting one acre from conventional to conservation tillage would conserve 2 inches of water per year. This figure has now been changed to 1.75 inches per acre, per year. The water savings are estimated to be 2,135,882 acre-feet over the 60-year planning horizon, which is equivalent to 2.03 percent of the total projected amount of water used to irrigate crops from 2010 to 2060. The estimated cost of conserving this water is $1,098,454 in implementation costs over the 60-year planning horizon.

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PRECIPITATION ENHANCEMENT

Lal K. Almas[1]

Strategy: Evaluate the impact of precipitation enhancement projects on water pumped from groundwater irrigation sources for Region A. Estimate potential water savings that will be generated by the two programs operating in the area. The cost of water savings is calculated using the annual cost estimates of North Plains Groundwater Conservation District and Panhandle Groundwater Conservation District.

Implementation: Assumed baseline use of this strategy in 2000 was 0 percent. Both the precipitation enhancement programs in Region A started in 2000. In Senate Bill 1, the precipitation enhancement strategy implementation goal was 100 percent from 2001. It has been further assumed that the implementation will remain at 100 percent during the planning period of 2001 to 2060.

Description:

The Texas Panhandle is a semi-arid region with varied rainfall. The variation in rainfall leads to variation in the year-to-year production of agricultural products under natural precipitation. Therefore, the Texas Panhandle relies on irrigation to both increase and stabilize production. The Ogallala aquifer is the primary source of irrigation water in the Texas Panhandle region. Due to limited recharge, continued pumping from Ogallala aquifer has resulted in a declining water table. The continued requirements of agricultural, municipal, and industrial sectors emphasize the critical need for alternative water management strategies. Precipitation enhancement is one of the water management strategies proposed in Senate Bill 1 to reduce irrigation water demand in Region A.

Precipitation enhancement is a process in which seeding agents, such as silver iodide, are introduced to stimulate clouds to generate more rainfall. This process is also commonly known as cloud seeding or weather modification. The cloud seeding process involves the intentional treatment of individual clouds or storm systems in order to achieve a beneficial effect without an adverse impact on human population or the environment. Dr. Vincent J. Schaefer, the father of modern weather modification, conducted the first field experiments on cloud seeding following his basic discoveries in 1946 at the General Electric Laboratory in Schenectady, New York. According to information provided by member countries to the World Meteorological Organization, cloud seeding projects are now being conducted in over 40 countries (Weather Modification Association, 1996).

The seeding agent in the process provides additional condensation nuclei for the moisture in the clouds. The process results in increased project area rainfall. The benefits that can be realized from increased rainfall from precipitation enhancement projects include increased agricultural production, economic sustainability and future

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[1] Assistant Professor (Agricultural Business and Economics), West Texas A&M University, Canyon, TX 79016.

growth, decreased surface and ground water consumption, increased reservoir levels, increased and higher quality forage for livestock and wildlife, and fire and hail suppression.

Documentation:

In addition to oxygen, nitrogen, and trace gases, the atmosphere contains variable amounts of water vapor. The amount of water vapor that exists in a given volume of air increases as the temperature rises. Relative humidity is one measure of water vapor concentration. The atmosphere has an abundance of cloud condensation nuclei; therefore, most clouds consist of small droplets of water vapor in high concentrations. Droplets in a typical cloud are so small that it takes about a million of them to make one rain drop. There are also aerosol particles in the atmosphere that cause cloud droplets to freeze or ice crystals to form directly from the water vapor. Important factors that control the initiation and amount of precipitation from a cloud are cloud size, cloud lifetime, and sizes and concentrations of the droplets and ice particles that make up the cloud. The typical large cumulus clouds have relatively few natural ice nuclei around which moisture in the air can nucleate and grow to form ice crystals or snowflakes high in the clouds, which then melt, and fall as rain. As a result, most of the cloud water vapor is never converted to raindrops.

Introducing silver iodide provides additional ice nuclei so that more of the cloud moisture can be transformed into ice particles, which grow to precipitation size and then melt and fall as raindrops. Silver iodide is able to initiate the precipitation process earlier in a cloud, making it more efficient and producing precipitation sized particles that can survive the fall through the dry sub-cloud layer and reach the surface as measurable rainfall. Precipitation enhancement can cause thunderstorm systems to grow wider, last longer, pull in more moist air from the surface, and transform that moist air into moisture droplets. Research has shown that precipitation enhancement can cause extra cloud growth on each side of the thunderstorm. This results in a longer life for the storm system, which may cause more rain to fall over a larger area.

Research related to weather modification over the period of 50 years and cloud seeding actually being performed in more than 40 countries support the evidence that such programs operated by qualified personals are, in fact, beneficial and can increase seasonal rainfall. The policy statements on weather modification issued by both the American Meteorological Society and the World Meteorological Organization are in favor of existing technology to enhance precipitation. The scientific community (National Academy of Sciences, 1975; Sax et al., 1975; Tukey et al., 1978) has generally acknowledged the cloud seeding experiments (Grant and Mielke, 1967; Mielke et al., 1971; Chappell et al., 1971; Mielke et al., 1981) providing the strongest evidence that seeding those clouds can significantly increase precipitation. Cotton and Pielke (1995) also concluded that the evidence of significant precipitation increases by static seeding of cumulus clouds came from the Israel I and II experiments. Rosenfeld and Woodley (1989; 1993) reported encouraging results from exploratory dynamic seeding experiments over West Texas. Analyses of the seeding of 183 convective cells had indicated that seeding increased the maximum height of the clouds by seven percent, the area of the cells by 43 percent, the durations by 36 percent, and rain volumes of the cells by 130 percent.

Researchers from the Texas Natural Resources Conservation Commission (TNRCC) have assessed the rain enhancement of the Colorado River Municipal Water District (CRMWD) from 1987 to 1990 and concluded that timely seeding with silver iodide prolongs the life of convective clouds, processes more moisture and produces significantly more rainfall. A statistical evaluation of the CRMWD's 25 year program has revealed that rainfall had been increased by 20 to 30 percent during the years of seeding. It has been found that rainfall totals to be 2.5 to 4.0 inches above normal during seeded years. In another study, rainfall data from a five-year cloud seeding program conducted for the City of San Angelo also supported the evidence that rainfall during the months of seeding had been increased 25 to 42 percent in the area where the seeding was concentrated.

The Texas Department of Agriculture has been conducting evaluations of ongoing seeding activities in Texas for the last two years. Results of these evaluations for 2002 indicate that all seeded thunderstorms in Texas (n = 897) have generated an additional 481,252 acre-feet of water with an approximate total cost of $4.8 million. This translates into one acre-foot of water at the expense of $10 through cloud seeding activities. It can be considered the most economical way of increasing water supply after natural precipitation that is totally free of charge (TDLR, 2004).

Methodology:

There are two projects in the Texas Panhandle Water Planning Area (Region A), which were established in the spring of 2000. Both programs cover approximately 8.2 million acres as their target area. The North Plains Groundwater Conservation District (NPGCD, 2004) and the Panhandle Groundwater Conservation District (PGCD, 2004), administer these two programs in Region A. For these two programs, seeding aircraft are launched from airports in Dumas and Pampa, respectively. NPGCD now owns the plane, building and other equipment to continue the program. Annual operating expenses are estimated as $200,000 (Bowers, 2004). PGCD has spent about $176,456 during 2003 as total cost of the program, out of which up to $88,228 was funded by the state. The district owns all the equipment and estimates to incur about $200,000 annually as operating expenses to run the weather modification program. Both the districts anticipate no funding from state for year 2004 and in the future.

This strategy determines the impact of precipitation enhancement activities in Region A. The impact is measured in terms of implementation cost of the program, water savings, and cost of water savings generated. The data source for the analyses is the Region A Water Demand Model that had been developed in Senate Bill 2-Task 2 Report (Marek et al., 2003). The effective rainfall available to crops was recalculated after considering the additional rainfall available due to precipitation programs and the revised water demand based on the crop acres in each county in Region A was estimated for the planning period 2001-2060. The difference between the water demand with implementation of the strategy and without the strategy is the amount of water that will be pumped less from the groundwater resources. Thus, the difference in water demand is considered the potential water saving due to implementing the precipitation enhancement program in Region A.

Baseline Analysis:

Precipitation enhancement was considered one of the management strategies by many water-planning regions during the first regional planning cycle. It was assumed that there were no acres utilizing benefits of precipitation enhancement in the baseline year of 2000. Therefore, projected water saving due to use of precipitation enhancement as a strategy was estimated as zero acre-feet (Almas et al., 2000). From the year 2001 to 2060, it has been assumed that all irrigated acres will be receiving the benefits of the precipitation enhancement programs being conducted by the two water conservation districts in Region A.

Results:

It is assumed that any additional rainfall in the area will reduce pressure on pumping water from groundwater resources especially for irrigation purposes. The assumed additional rainfall due to cloud seeding and weather modification programs in the area ranges from one inch to two inches during the cropping season of six months (April to September). The distribution of that additional rainfall has also been taken into account for calculating the water requirement for each crop in each county and then the revised water demand is calculated using the methodology used in Task 2 of the Senate Bill 2 water planning project for Region A. The estimated water savings are then calculated as the difference in water demand with and without the implementation of the precipitation enhancement strategy. The rainfall distribution assumptions have been based on the historical trend of rainfall during six months of cloud seeding operations. Analyses of historical rain data from 1940 to 1997 for the 21 county area in Region A indicates that 73 percent of annual rain falls during April to September and the distribution of rainfall in these six months is 11 percent, 20 percent, 20 percent, 18 percent, 17 percent, and 14 percent, respectively. The historical distribution has been used to calculate the effective rainfall.

The projected water savings of one inch per acre assuming a historical distribution have been compiled and presented in Table 1. The implementation costs of the strategy including yearly operating cost, airplane replacement cost every 20 years and the cost of water saved on per acre-foot basis are also given in Table 1. It is estimated that 4,105,680 acre-feet of water is saved from 2001 to 2060 by continuing precipitation enhancement programs in Region A with the assumption that one inch of additional rainfall is generated during each year. This equates to a 3.89 percent reduction in the total projected irrigation water use. The total cost of generating the water saving is estimated to be $25.80 million over the 60-year planning period. Thus, the cost of water saved comes to $6.28 per acre-foot.

Table 1. Estimated Affected Acreage, Cost of Implementation, Regional Impact, Water Savings, and Cost of Water Savings

	2010	2020	2030	2040	2050	2060	**Total**
Affected Acreage	1,502,159	1,502,159	1,502,159	1,502,159	1,502,159	1,502,159	
Implementation Cost (Millions)							
Operating Expense	$4.00	$4.00	$4.00	$4.00	$4.00	$4.00	**$24.00**
Aircraft Replacement		$0.60		$0.60		$0.60	**$1.80**
Regional Impact (Millions)							**$0**
Water Savings (Acre-Feet)	684,280	684,280	684,280	684,280	684,280	684,280	**4,105,680**
			Cost of Water Savings Generated ($ per Acre-Foot)				
				Implementation Cost / Water Savings			$6.28
				Regional Impact / Water Savings			$0.00

Summary and Conclusions:

The precipitation enhancement programs in Texas and other parts of the country are being operated to reduce groundwater pumpage. The cloud seeding projects use the latest technological developments in science to chemically squeeze more rain out of clouds. Water conservation districts and county commissions have generally accepted the technology of precipitation enhancement as one element of a long-term, water management strategy. Assuming one-inch of additional rainfall is generated under this strategy, 4,105,680 acre-feet of water will be saved, or 3.89 percent of the total projected irrigation water use. The cost of generating these water savings is $25.8 million or $6.28 per acre-foot. It should be noted that additional benefits such as livestock grazing, recreational benefits, increased water supply in reservoirs, etc. have not been accounted for in this analysis. This strategy is an economical tool to ensure that growing populations have enough water to meet their future needs. To date, however, there is no statistical proof that the concept produces more water.

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CONVERTING IRRIGATED CROPS TO DRYLAND

DeDe Jones and Dustin Gaskins[1]

Strategy: Evaluate the implications of converting from irrigated cotton, sorghum, and wheat to dryland in Region A. The cost of water savings is the loss in land values when comparing irrigated versus dryland acreage, and the loss in gross crop receipts.

Implementation: The assumed rate of conversion is 5 percent by 2010, 10 percent by 2020, and 15 percent by 2030 as proposed in Senate Bill 1. No additional changes are assumed to occur beyond 2030.

Description & Documentation:

Water conservation has become increasingly important to agriculture on the Texas High Plains. Since crop production in this area is generally restricted by a lack of adequate rainfall, ground water irrigation from the Ogallala Aquifer has been widely used to overcome this limitation. However, continued withdrawals from the Aquifer at current rates will likely result in eventual resource depletion. Producers in Region A must begin to evaluate water management strategies for reducing irrigation demands in order to maintain economic stability. One strategy proposed in Senate Bill 1 was the conversion from irrigated to dryland cropping systems. This conversion will have a significant impact on the economic value of Texas High Plains agriculture. Over the past several decades, dryland production in Region A has become primarily limited to wheat, grain sorghum, and cotton. These crops have proved themselves capable of growing under drought conditions that commonly plague the area.

Many studies have been conducted to evaluate the long-term viability of Texas groundwater supplies. Arabiyat, Segarra, and Willis (1999) state that of the 14 million acres irrigated in the U.S. where ground water aquifers are declining, 4 million are located in Texas. The majority of this acreage is located in the Texas High Plains, where the Ogallala Aquifer is the main source of irrigation water. The authors emphasize that over the last three decades, saturated thickness of the aquifer has significantly decreased as a result of continued overdraft. Moreover, pumping lift, the distance between the surface and water table, is expected to continually increase over time since sources of recharge are limited. They estimate that 30 to 35 percent of the pre-development ground water resources in the THP have been already mined, and continued overuse will result in resource depletion. Another study conducted by Stewart, Musick, and Dusek (1982) indicates that High Plains irrigation accounts for 40 percent of all irrigated cropland in the USA. The Ogallala Aquifer, the primary source of irrigation water for the Great Plains, is being rapidly depleted in some areas, particularly in the Southern High Plains. The authors indicate that irrigation from ground water in the SHP is expected to decrease rapidly in future years because of declining aquifer levels.

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[1] Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106 and Program Specialist – Risk Management, Texas Cooperative Extension, Amarillo, TX 79106.

While converting from an irrigated to dryland cropping system may be a viable economic alternative for many Region A producers, research indicates that only a limited number of dryland crops can be produced profitability in this area. The primary dryland crops are winter wheat, grain sorghum, and upland cotton. Musick, Jones, Stewart, and Dusek (1993) state that winter wheat is a major dryland crop grown in the U.S. Southern High Plains, second only to cotton. The crop has excellent drought tolerance, is deep rooted and widely grown under limited (deficit) irrigation. The authors feel that because of declining groundwater storage and well yield from pumping the Ogallala aquifer, limited irrigation should be widely practiced on crops such as wheat that possess drought tolerance and can be grown successfully without irrigation.

Grain Sorghum also has dryland profit potential. Armah-Agyeman, Loiland, Karow, Payne, Trostle, and Bean (2002) assert that sorghum's leaves and root system are what make the crop drought tolerant and give it superiority over corn and other cereals. The leaves and stems are covered with a wax coating that protects them from drying out. The sorghum plant also has an extensive root system that can penetrate to depths of 5 feet or more. Because of this extensive and efficient root system, the plant acquires more available soil moisture than many other crops. The authors state that sorghum is adapted to a wide range of soil and climatic conditions. It is well able to withstand both high temperatures and moisture limitations. It will always out-yield corn in low moisture conditions. Another study conducted by Jones and Johnson (1982) indicates that sorghum is well adapted to dryland grain production in the Southern Great Plains. The periods of peak water use by sorghum and naturally occurring high summer rainfall frequently coincide to produce high grain sorghum yields. They state that when water stress occurs during drought periods, sorghum growth slows and becomes practically dormant. Plants resume growth when sufficient solid water is again available; thus, sorghum usually produces some grain, even under adverse moisture conditions.

Cotton is another drought resistant crop whose deep root system enables it to produce some lint yields even under limited soil water conditions. A study conducted by Blackshear and Johnson (2000) found that dryland cotton production in the Texas High Plains was profitable in three out of every five years, and resulted in a positive net income when evaluated by the five-year average. Thus, the authors indicate that dryland cotton production seems to be profitable on the Texas High Plains in the medium to long run. Another study by McWilliams (2003) found that if managed properly, cotton can withstand drought on infrequently irrigated, coarse-textured, sandy soil with hot, dry conditions from June 1 through the end of August. Even during peak bloom, cotton uses only 0.3 to 0.4 inches of water per day, and responds better than many other crops during drought years due to its ability to subsist on limited moisture.

Methodology:

This analysis evaluates the impact of converting irrigated acreage to dryland. This impact is measured in terms of cost of implementation, water savings, regional economic impacts, and cost of water savings generated. The primary source of data for this analysis is the Region A Water Demand Model that was developed in Senate Bill 2 –

Task 2. This model uses Farm Service Agency (FSA) acreages that have been previously approved by the Texas Water Development Board. Average water use figures for the three irrigated crops analyzed (sorghum, cotton, and wheat) were also obtained from the model.

The cost of implementing this water conservation strategy is evaluated in terms of reduced land values. Texas Rural Land prices are determined through the Real Estate Center at Texas A&M University. This resource provides estimates of irrigated land with fair water for Regions 1,2, and 5 for Fall 2001. These values are then compared to dryland values in the same regions to determine the loss in value. Land that has sufficient water available for irrigation is worth a premium compared to land with limited irrigation resources.

Water savings generated by this strategy are measured in acre-feet. These savings are calculated by first making the proposed changes to the baseline FSA acreages. The adjusted acreage is then multiplied by the corresponding crop’s average water use number. As acreage shifts from irrigated crops to dryland production, water savings are generated.

The regional economic impact of this strategy is analyzed in terms of the change in gross receipts on the affected acreage. Gross receipts are calculated by using a five-year (1998-2002) average regional price and yield. The prices were obtained from Master Marketer and the Texas Agricultural Statistics Service (TASS), while yields were acquired from TASS. These regional average yields and prices were then multiplied by the corresponding amount of planted acreage for each crop.

The cost of water savings is evaluated in two ways. The first, gives an indication of the cost incurred by producers to generate an acre-foot of water savings. This measure is generated by dividing the total change in land values by the amount of water conserved. The second method of estimating the water savings cost, evaluates the cost to the region of saving an acre-foot of water. This estimate is calculated by dividing the change in gross revenues by the total water savings.

Baseline Analysis:

In the base year, 2000, the approved FSA numbers indicate there were a total of 797,423 acres planted to irrigated sorghum, cotton, and wheat in the High Plains region (Table 1). Also presented in Table 1 are the five-year (1998-2002) yields and prices for each crop. Long Term Average (LTA) applied irrigation numbers from the Region A Water Use Model show that 687,636 acre-feet of irrigation water was applied to the three crops analyzed in the year 2000 (Table 2).

The following changes in acreage are assumed: acreage planted in irrigated cotton, sorghum, and wheat is converted to dryland cotton, sorghum, and wheat acreage. From the 2000 baseline year until 2009, it is assumed that none of the acres have undergone a shift in the type of production methods. It is expected that 5 percent of the acreage changes production practices from 2010 to 2019, that a total of 10 percent change from 2020 to 2029, and that 15 percent change from 2030-2060.

Table 1. Estimated Yields, Prices, and Acreage for Panhandle Crops

	2000 FSA Acreage	Land Value	Yield*	Price*
Irr Wheat	643,806	$600	46.28 Bu	$2.70 / Bu
Dry Wheat		$275	25.35 Bu	$2.70 / Bu
Irr Sorghum	116,612	$600	45.23 Cwt	$3.70 / Cwt
Dry Sorghum		$275	20.32 Cwt	$3.70 / Cwt
Irr Cotton	37,005	$600	630 Lbs	$0.45 / Lb
Dry Cotton		$275	277 Lbs	$0.45 / Lb
Irr Cotton Seed	37,005		0.53 Tons	$102 / Tons
Dry Cotton Seed			0.23 Tons	$102 / Tons
Total	**797,423**			

Table 2. Amount of Irrigation Water Applied by Crop in 2000

	Sorghum	Cotton	Wheat	**Total Irr** (acre-feet)
Avg Irr (inches / acre)	9.98	10.69	10.39	
Total Irr (acre-feet)	97,012	32,972	557,653	**687,636**
% Total Applied Irr	14%	5%	81%	

<u>Results:</u>

It is estimated that by converting from irrigated to dryland will cause a reduction in land values. According to the Texas A&M Rural Land Report, the value of irrigated land with fair water is $600 per acre. The value of dry cropland is estimated at $275 per acre. Therefore, the net loss in land value for medium water use is $325 per acre (Table 3). From 2010 –2019, 39,871 acres undergo such a shift resulting in a loss in value of approximately $13 million (Table 3). The value of land in Region A is reduced by another $13 million from 2020 – 2029 when an additional 5 percent of the irrigated acreage is assumed to be converted to dryland production practices. Finally, a further $13 million loss in land value takes place from 2030-2060 with the shift of another 5 percent of the irrigated acres. This $39 million loss is the cost implementing this water saving strategy.

Water savings are calculated on both a per acre and total value basis. It is assumed that converting irrigated cotton acres in Region A to dryland cotton will result in a water savings of 10.69 inches per acre. Converting irrigated sorghum acres to dryland sorghum projects a water savings of 9.98 inches per acre. Finally, converting irrigated wheat acres to dryland wheat results in 10.39 inches per acre in water savings. It is estimated that 343,818 acre-feet of water is saved from 2010 – 2019 by converting 5 percent of the irrigated acreage to dryland (Table 3). The region experiences 687,636 acre-feet of water savings from 2020 – 2029 10 percent shift in acreage. Total water savings increase to 1,031,454 acre-feet of water from 2030 – 2060 when 15 percent of the irrigated acreage in Region A is shifted to alternate production methods. The total water savings over the 60-year analysis period are estimated to be 5,157,272 acre-feet, or 4.89 percent of the total projected irrigation water use.

The impact on the regional economy must be considered when looking at making such substantial changes to the area's primary source of revenue. This impact is measured in terms of the resulting change in gross receipts. This measure is used as input into socio-economic model such as IMPLAN to estimate the total impact on the regional economy. Cotton will experience a net decrease in gross receipts of $189.45/acre, sorghum will experience a decline of $92.17/acre, and wheat indicates a decrease of $56.51/acre. It is estimated that Region A experiences an annual reduction in gross revenues of $2.7 million from 2010 – 2019 (Table 3) with a 5 percent reduction in irrigated acreage. Furthermore, a $5.4 million annual reduction in gross receipts is experienced from 2020 – 2029 and the yearly reduction in gross revenue increases to $8.1 million for the rest of the analysis period. The non-discounted total reduction in gross receipts is $406 million over the 60-year planning horizon.

The cost of generating water savings must be weighed against the benefit. To accomplish this, a "price tag" needs to be given to the water that is conserved. It is estimated that the cost of generating each acre-foot of water conserved is $7.54 (Table 3). However, the cost to the region is much higher. It is estimated that for each acre-foot of water saved the economy in Region A will experience a $78.72 loss in gross revenue.

Table 3. Estimated Affected Acreage, Cost of Implementation, Regional Impact, Water Savings, and Cost of Water Savings

	2010	2020	2030	2040	2050	2060	**Total**
Affected Acreage	39,871	79,742	119,613	119,613	119,613	119,613	
Implementation Cost (Millions)	$13	$13	$13				**$39**
Regional Impact (Millions)	-$27	-$54	-$81	-$81	-$81	-$81	**-$406**
Water Savings (Acre-Feet)	343,818	687,636	1,031,454	1,031,454	1,031,454	1,031,454	**5,157,272**

Cost of Water Savings Generated ($ per Acre-Foot)

Implementation Cost / Water Savings	$7.54
Regional Impact / Water Savings	-$78.72

Summary and Conclusions:

The original assumptions of this strategy under Senate Bill 1 were that irrigated cropland planted to cotton, sorghum, and wheat in Region A is shifted to dryland at a rate of 5 percent by 2010, 10 percent by 2020, and 15 percent by 2030. No additional changes were assumed to occur beyond 2030. Converting irrigated acreage to dryland production practices results in significant water savings. These savings, 5,157,272 acre-feet, are equivalent to 4.89 percent of the total projected amount of water that is used to irrigate crops from 2000-2060. The estimated cost of conserving this amount of water is $39 million in implementation costs and $406 million in gross revenue is estimated to be lost over the 60-year planning horizon.

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