Policy Modeling Framework for Groundwater Management for Irrigated Agriculture in the Northern Texas High Plains

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Abstract: The continued decline in the availability of water from the Ogallala Aquifer has led to an increased interest in conservation policies designed to extend the life of the aquifer to sustain rural economies in the Texas Panhandle. This study evaluates the effectiveness of five policies in terms of changes in the saturated thickness of the aquifer as well as the impact each policy has on crop mix, water use per acre, and the net present value of farm profits over a sixty-year planning horizon for the northwestern four counties of the Texas Panhandle.

Key Words: Ogallala Aquifer, Groundwater Conservation, Water Management Policy, Texas Panhandle

Introduction:

The availability of water especially for irrigated agriculture in the Texas Panhandle is a major concern, as is the conservation of the limited supply of water in the region. The Texas High Plains area has a semi-arid climate and average low rainfalls which results in little surface water being available year-round for agriculture. Thus, more than 90% of the water used in agriculture in the High Plains area comes from the Ogallala Aquifer (Stewart, 2003 and Jenson, 2004). The aquifer covers about 36,080 square miles and it currently has a supply of water of approximately 6.1 million acre feet , which is expected to decline to 4.8 million acre feet by 2060 (Jenson, 2004). From 1994 to 2004, the aquifer declined at an average of 1.28 feet per year (Jenson, 2004). Adding to the problem is the low recharge rate of the aquifer in the High Plains area (Postel, 1998). In the southern region, the recharge rate has been reported to be as low as 0.024 inches per year from precipitation (Ryder, 1996).

The use of low-energy-application (LEPA) and low-energy-spray-application (LESA) have allowed for more efficient use of water in the region (Howell, 2001). However, producers have had the benefit of increased technology in drilling and installing these systems, which has led to increased irrigation use. In the southern High Plains, which uses intense irrigation, the decline in the water table has been estimated to be between 50 and 100 feet (Ryder, 1996). A contributing factor to the increased use of groundwater comes from the state laws covering the right of capture of ground water beneath the land, by which the land owner may capture the water beneath the land regardless of the effect on nearby or distant users of the water supply (Stewart, 2003). A survey conducted in 2003 showed that of 63,602 operating wells, only 4,530 wells had a meter installed (NASS, 2004). Finally, recent trends in purchasing “water rights” and the potential uses of the water associated with these rights threaten to result in further depletion.

The main goal of any conservation policy is to limit the use of a resource in an effort to preserve the quantity of that resource. Thus the purpose behind a policy to restrict groundwater use is to prevent aquifer depletion in an effort to assure a continued supply of water for many years to come. This is very important when a region is rural in nature and in which the local economy is heavily dependent on agriculture. Such is the case in the Texas Panhandle. In an effort to increase returns, producers have focused heavily on producing irrigated crops, due in large part to low energy costs to apply irrigation water in the earlier years, and more recently the adoption of new technology that improves efficiency and reduces costs. However, continued pumping of groundwater at the present levels will draw the aquifer down to the point where it will no longer be economically feasible to irrigate, which will result in a greater negative economic impact for the region. The implementation of a water conservation policy will ideally prolong the life of the aquifer in an effort to maintain the economy of the rural Texas Panhandle for many years to come. In choosing an appropriate policy, the benefits (in this case decreased drawdown of the aquifer) need to be weighed with the costs (reduced producer and resource supplier revenues due to reduced irrigated crop acres).

Research Objective:

The scope of this study is the evaluation of a baseline and five alternative policies designed to conserve groundwater in Dallam, Hartley, Moore, and Sherman counties in the Texas Panhandle. These counties were selected because a significant portion of grain production in the Texas Panhandle comes from these counties (Table 1). They showed a significant level of water depletion in the baseline scenario during the sixty-year simulation. This study focuses on the changes saturated thickness, water use, crop mix (irrigated versus dry land), and the net present value of profits in the four-county area of the Texas Panhandle overlying the Ogallala aquifer over a sixty-year planning horizon. The results of the study allow a comparison between the baseline and each of the five policies in terms of water use reduction as well as the economic impacts of the policies in these counties.

Data and Research Methods:

This study utilizes optimization models that were developed using Generalized Algebraic Software (GAMS), including a model for the baseline as well as one for each of five policy alternatives for each of the four counties in this study. The models include production functions for six primary irrigated and dryland crops, including corn, cotton, peanuts, sorghum, soybeans, and wheat. These production functions were estimated using data generated using the CroPMan management modeling software developed by the Texas A&M Blackland Research Center at Temple, Texas. CroPMan simulations were run for each crop under different amounts of irrigation for each of the four counties, with the yields being regressed against the amounts of irrigation to develop the productions functions. The GAMS models also include county-specific data such as aquifer recharge rate, acres planted in each crop and system in the base year, budgeted 2007 production and irrigation costs, actual 2007 crop prices, and a three-year average dryland yield as reported by the National Agricultural Statistics Service.

The specific policy models also include constraints for water usage, crop substitution, and dryland substitution, as well as revenue, cost, and hydrologic calculations. Initial saturated thickness values for each county were obtained from the Texas Tech University Center for Geospatial Technology, with the initial (2004) average saturated thickness for Dallam County being 128 feet, Hartley County 153 feet, Moore County 162 feet, and Sherman 182 feet. These values were used as the beginning saturated thickness for each county in the baseline and policy GAMS models. Texas Water Development Board's "Report 347" (2001) was used to obtain the initial irrigated acreage data, with the four-county area consisting of 1,027,167 cropland acres, of which 807,008 acres are irrigated. Of these irrigated acres, 78.6% are irrigated with LEPA-style center pivot sprinkler systems. Dallam County consists of 278,067 cropland acres, with 247,141 acres being irrigated, 246,238 of which are irrigated with center pivot systems and the rest furrow irrigated. Hartley County includes 235,733 cropland acres, including 187,169 irrigated acres, with 185,169 under center pivot sprinkler, 2,000 furrow, and 65 drip irrigation. In Moore County, there are 233,267 cropland acres, with 143,787 acres under irrigation, of which 128,725 are sprinkler irrigated and 15,062 are furrow irrigated. Sherman County has 280,100 cropland acres with 228,911 of these being irrigated, 217,931 sprinkler, 10,980 furrow, and 12 drip.

These models were run optimizing the net present value of profits over a sixty year horizon, providing detailed results showing changes in the average saturated thickness of the aquifer, net present value for returns, the level of water use, and the acreage planted under each crop and system (dry land or irrigated) for each county for each of the sixty years modeled.

The baseline scenario assumes that no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. The only restrictions in the models for the target area are a maximum of 36 inches of irrigation is allowed per crop per year and the saturated thickness is not allowed to fall below 20 feet. The specific conservation scenarios include the adoption of biotechnology, the adoption of irrigation technology, a mandatory water use restriction, the temporary conversion (TCD) of irrigated acreage to dryland production, and the permanent conversion (PCD) of irrigated acreage to dryland production. The biotechnology adoption scenario assumes that drought resistant crops are used, resulting in a 1%

decline in water use each year while crop yields increase by 0.5% each year during the sixty-year simulation. In the irrigation technology scenario, it is assumed that 10% of the irrigated acreage under furrow irrigation (65% efficiency) and LEPA sprinkler irrigation (95% efficiency) is replaced by drip irrigation systems operating at 99% efficiency.

The water-use restriction scenario assumes that water use is reduced by 1% each year during the sixty-year planning horizon. In the temporary conversion to dryland scenario, the assumption is that 2% of irrigated acreage is switched to dryland production each year for the first 5 years for a total of 10% by year 5. This acreage is then allowed to re-enter irrigated production after year 15 of the scenario. Finally, the permanent conversion to dryland scenario assumes that 2% of irrigated acreage is switched to dryland production each year for the first 5 years for a total of 10% by year 5. This acreage remains in dryland production for the remainder of the sixty-year simulation.

The results from the baseline and each policy alternative were then compared to evaluate the effectiveness of each policy in conserving water in terms of reduced aquifer withdraws and water usage, the change in crop mix (irrigated versus dryland acreage), and the economic implications of each policy in terms of net present returns per acre for the four counties in this study.

Results and Discussion:

The beginning regional average saturated thickness was 152.3 feet, with Dallam County having a thickness of 128 feet, Hartley 153 feet, Moore 162 feet, and Sherman 192 feet. In Dallam County, the saturated thickness declined 61.4% reaching 49.4 feet, Hartley 52.1% at 73.5 feet, Moore 65.5% at 60.4 feet, and Sherman 61.2% at 74.12 feet (Table2).

As the water level declines, well capacity drops and irrigation cost rises, leading to less water being required to reach a profit maximizing level of water use. As the per acre water use is decreased, producers shift production from irrigation-intensive crops to crops that require less water or to dryland crops.

When producers shift their production away from irrigated crops the regional average net income per acre drops 48% from $136.07 to $90.70 per acre for Dallam County. These returns yield an average net present value per acre in the baseline scenario of $4,558. Results for other counties are also presented in Table 5.

In the biotechnology adoption scenario, in Dallam County, the saturated thickness declines 60.4% to reach a level of 50.7 feet, Hartley declines 51.5% to reach 74.1 feet, Moore 52.7% to reach 76.6 feet, and Sherman 50.0% to reach 91.0 feet (Table 2). Irrigated acres as a percent of all cropland acres in this scenario increase above the baseline in all four counties (Table 3). It should be noted that this increase is due in part to the increased yields and their associated net returns partially offsetting the increased cost to irrigate as the aquifer declines as well as the fact that reduced water use and aquifer depletion in earlier years of the simulation allow more water to be available in later years. Detailed results for each county are presented in Table 3. Average net income per acre increases significantly due to the increased yields this scenario provides, reaching $180.83 per acre or 99.4% more than the baseline (Table 4). This equates to a net present value of $5,950 per acre, which is 31% greater than in the baseline (Table 5). It should be noted that the assumptions in this scenario are based on the future availability of drought resistant seed varieties that are not currently available to producers.

Conclusion:

The policies that showed the best results in terms of conserving the water available in the Ogallala Aquifer were the biotechnology adoption scenario and the water use restriction scenario. Both of these policies assume a 1% reduction in water use per year during the 60-year planning horizon. The permanent conversion to dryland scenario proved to be the third best in water conservation, though it was just marginally better than the temporary conversion to dryland and the irrigation adoption scenarios. The effect of each policy on the saturated thickness in the individual counties varied primarily due to the dependence each county has on irrigated acreage. For example, Sherman County had the greatest water savings in terms of ending saturated thickness in both the biotechnology and water use restriction scenarios when compared to the baseline scenario, but it also had the second least irrigated acreage as a percent of total cropland acres.

There are also differences among the counties in terms of the specific crops planted in each contributing to differences in the scenario results. Dallam and Hartley have a high percentage of their cropland planted in irrigated corn and irrigated wheat, with Dallam having 46.6% in irrigated corn and 28.4% in irrigated wheat and Hartley having 49.8% in irrigated corn and 25.4% in irrigated wheat. Moore and Sherman counties, however, have a greater reliance on dryland crops. In Moore County, 34.5% of all cropland acreage is in dryland wheat, 23.6% in irrigated corn, and 14.5% in irrigated wheat. In Sherman County, dryland wheat accounts for 32.3% of all cropland acres, while irrigated corn accounts for 25.3% and irrigated wheat 24.3%.

In terms of economic costs, the biotechnology adoption policy by far provides the greatest net returns and net present values. However, as was previously mentioned, the yield increases provided in the models are based on seed varieties that are not yet available to producers. The next best policy for the region and each individual county in terms of net present value of returns was the irrigation adoption technology, though it ranked last (along with the temporary conversion to dryland policy) in terms of reducing aquifer depletion. The water use restriction policy, though as effective as the biotechnology adoption policy, had the lowest net present value of returns, showing that at present it would be the best conservation policy but at a significant cost to producers.

While it is obvious that something needs to be done concerning the depletion of the Ogallala Aquifer, policy makers are faced with a daunting task of determining which policy would be most effective at conserving the water currently available, while at the same time considering the economic costs of the policy in terms of lost producer returns, not to mention the resulting economic impacts on resource suppliers and the community over all. In deciding on a policy focused on conserving water, policy makers also need to consider the impact that each policy will have on other segments of the industry, as well as on the communities that rely on the industry. There will always be tradeoffs between the policy objective and the consequences associated with that policy. This study was aimed at providing more information to policy makers concerning the effectiveness of each of the five policies at conserving the Ogallala Aquifer in the region and the individual counties, while also providing an insight into the impact each policy would have on net farm returns during the 60-year planning horizon.

Bibliography:

Almas, Lal K., W. Arden Collette, and Seong C. Park. 2006. "Economic Optimization of Groundwater Resources in the Texas Panhandle." Selected Paper presented at the SAEA Annual Meeting, Orlando, Florida, February 5-8, 2006.

Howell, Terry A. 2001. "Enhancing Water Use Efficiency in Irrigated Agriculture." Agronomy Journal, 93, pp 281-289 (2001).

Jensen, R. 2004. Ogallala Aquifer: Using improved irrigation technology and water conservation to meet future needs. Texas Water Resource Institute. http://twri.tamu.edu/newsarticles.php?view=2004-08-05, accessed December 8, 2005.

NASS (National Agricultural Statistical Service). 2004. Farm and Ranch Irrigation Survey (2003). 2002 Census of Agriculture, http://www.nass.usda.gov/census, accessed December 2, 2005.

Park, Seong C. 2005. "Economic Optimization of Groundwater Resources in the Texas Panhandle." M.S. Thesis, West Texas State University, Division of Agriculture, Canyon, Texas.

Postel, Sandra A. 1998. "Water for Food Production: Will There be Enough in 2005." BioScience, 48:8, pp 629-637 (1998).

Ryder, P.D. 1996. (United States Geological Survey). Geological Survey-Ground Water Atlas of the United States, Oklahoma, and Texas. http://capp.water.usgs.gov/gwa/ch_e/E-text5.htnl, accessed December 16, 2005.

Stewart, B.A. 2003. Aquifers, Ogallala. Encyclopedia of Water Science, pp. 43-44 (2003).

Table 1. Major crop acres and production in study area and Texas Panhandle, 2007.

Crop	Four County Area Acres Harvested (1,000 ac.)	Four County Area Production (1,000 bu)	Texas Panhandle (26 Counties) Acres Harvested (1,000 ac.)	Texas Panhandle (26 Counties) Production (1,000 bu)	Study Area Comparison with Texas Panhandle	
Wheat	**399.5**	**19,277**	**1,753.3**	**77,571.0**	**23%**	**25%**
Irrigated	190.1	12,046	474.4	28,572.0	40%	42%
Nonirrigated	209.4	7,231	1,278.9	48,999.0	16%	15%
Sorghum	**73.9**	**5,799**	**397.9**	**26,301.0**	**19%**	**22%**
Irrigated	49	4,901	169.2	15,682.0	29%	31%
Nonirrigated	24.9	898	228.7	10,619.0	11%	8%
Corn	**390.8**	**83,543**	**736.9**	**154,889.0**	**53%**	**54%**
Upland Cotton	24.8	58	350.6	700.3	7%	8%
Irrigated	21.1	54	193.0	503.3	11%	11%
Nonirrigated	3.7	4	157.6	197.0	2%	2%

Table 2. Change in Saturated Thickness (feet) by County

Policy Scenario:	Dallam Year 1	Dallam Year 60	Hartley Year 1	Hartley Year 60	Moore Year 1	Moore Year 60	Sherman Year 1	Sherman Year 60
Baseline	128.0	49.40	153.0	73.48	162.0	60.42	182.0	74.12
Biotechnology	128.0	50.70	153.0	74.14	162.0	76.60	182.0	91.02
Change from Baseline		*2.63%*		*0.90%*		*26.77%*		*22.79%*
Irrigation Technology	128.0	49.30	153.0	73.51	162.0	60.42	182.0	74.12
Change from Baseline		*-0.20%*		*0.04%*		*0.00%*		*0.00%*
Water Use Restriction	128.0	50.70	153.0	74.14	162.0	76.60	182.0	91.02
Change from Baseline		*2.63%*		*0.90%*		*26.77%*		*22.79%*
Temporary Conversion	128.0	50.20	153.0	74.50	162.0	60.42	182.0	74.57
Change from Baseline		*1.62%*		*1.39%*		*0.00%*		*0.6%*
Permanent Conversion	128.0	50.30	153.0	74.76	162.0	60.42	182.0	75.2
Change from Baseline		*1.82%*		*1.75%*		*0.00%*		*1.45%*

Table 3: Irrigated Acres as a percentage of Total Crop Acres by County

	Dallam		Hartley		Moore		Sherman	
Policy Scenario:	**Year 1**	**Year 60**	**Year 1**	**Year 60**	**Year 1**	**Year 60**	**Year 1**	**Year 60**
Baseline	81.39%	25.46%	84.22%	35.87%	59.22%	21.86%	63.40%	28.98%
Biotechnology	81.39%	27.37%	84.22%	37.76%	59.22%	23.35%	63.40%	30.74%
Change from Baseline		7.50%		5.27%		6.81%		6.08%
Irrigation Technology	81.39%	24.91%	84.22%	35.69%	59.22%	22.01%	63.40%	29.00%
Change from Baseline		-2.16%		-0.48%		0.68%		0.07%
Water Use Restriction	81.39%	24.79%	84.22%	34.25%	59.22%	22.16%	63.40%	27.93%
Change from Baseline		-2.63%		-4.49%		1.37%		-3.62%
Temporary Conversion	81.39%	26.32%	84.22%	36.87%	59.22%	21.86%	63.40%	29.33%
Change from Baseline		3.39%		2.79%		0.00%		1.21%
Permanent Conversion	81.39%	26.43%	84.22%	37.13%	59.22%	21.86%	63.40%	29.83%
Change from Baseline		3.81%		3.53%		0.00%		2.93%

Table 4: Change in Average Net Income $ per Acre by County

	Dallam		Hartley		Moore		Sherman	
Policy Scenario	**Year1**	**Year60**	**Year1**	**Year60**	**Year1**	**Year60**	**Year1**	**Year60**
Baseline	136.07	90.70	124.50	105.12	107.80	119.89	125.51	108.11
Boitechnology	140.14	180.83	123.07	210.50	109.66	247.89	129.25	209.09
Change from Baseline	2.99%	99.37%	-1.15%	100.25%	1.73%	106.77%	2.99%	93.41%
Irrigation Technology	136.35	87.13	124.59	103.41	107.80	118.73	125.62	106.06
Change from Baseline	0.21%	-3.94%	0.07%	-1.62%	0.00%	-0.97%	0.09%	-1.89%
Water Use Restriction	137.64	89.60	120.45	98.37	107.80	121.99	127.16	104.22
Change from Baseline	1.15%	-1.21%	-3.25%	-6.42%	0.00%	1.75%	1.31%	-3.59%
Temporary Conversion	136.28	91.97	129.22	106.48	107.80	119.89	125.54	108.66
Change from Baseline	0.15%	1.40%	3.79%	1.30%	0.00%	0.00%	0.03%	0.52%
Permanent Conversion	136.64	92.13	129.51	106.84	107.80	119.89	125.78	109.46
Change from Baseline	0.42%	1.58%	4.02%	1.64%	0.00%	0.00%	0.22%	1.25%

Table 5: Average Net Present Value of Returns per Acre by County

Policy Scenario:	Dallam	Hartley	Moore	Sherman
Baseline	**$4,558.20**	**$4,665.37**	**$4,471.77**	**$4,755.60**
Biotechnology-	$5,950.03	$6,145.64	$5,696.20	$5,681.33
Change from Baseline	30.53%	31.73%	27.38%	19.47%
Irrigation Technology-	$4,348.33	$4,578.63	$4,410.32	$4,630.63
Change from Baseline	-4.60%	-1.86%	-1.37%	-2.63%
Water Use Restriction-	$4,471.20	4,475.62	4,246.55	4,293.55
Change from Baseline	-1.91%	-4.07%	-5.04%	-9.72%
Temporary Conversion-	$4,414.39	$4,521.52	$4,403.15	$4,626.37
Change from Baseline	-3.16%	-3.08%	-1.53%	-2.72%
Permanent Conversion-	$4,397.54	$4,494.15	$4,402.78	$4,576.73
Change from Baseline	-3.52%	-3.67%	-1.54%	-3.76%