Estimating the Potential to Reduce Agricultural Irrigation Water Demand in West Central Texas

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ABSTRACT

The purpose of this paper is to assess future agricultural irrigation demand and estimate the potential for water savings from advanced irrigation technology adoption in Region F, an area encompassing 32 West Central Texas counties. This involved calculating irrigation water demand based on existing cropping activities, irrigation technologies and typical irrigation application rates and assessing the potential water savings resulting from adoption of the most feasible irrigation technology. Results suggest that certain counties within Region F (Borden, Glasscock, Loving, Midland, Reagan, Reeves, and Tom Green) will be unable to meet irrigation demands even with utilization of the most efficient technology. It can be anticipated that in those counties, some portion of the irrigated acres will shift to non-irrigated crop production or to other uses.

KEYWORDS: irrigation demand, furrow irrigation, surge flow, MESA, LESA, LEPA

As a result of the passage of Senate Bill 1 (SB1) in 1997, water planning in Texas became the domain of regional planning groups rather than the Texas Water Development Board. SB1 allows individuals representing numerous interest groups to serve as members of Regional Water Planning Groups (RWPG) to prepare regional water plans for their respective areas. These plans map out how to conserve water supplies, meet future water demand needs, and respond to future droughts in the planning areas. The purpose of this paper is to assess future agricultural irrigation demand and estimate the potential for water savings from advanced irrigation technology adoption in West Central Texas or Region F as the Texas Water Development Board designates it.

Crop production in Region F is diverse across the region due to differing climatic conditions, soil types, water sources (groundwater and surface), water quality and cropping mixes. To facilitate the investigation of feasible irrigation technologies, sub-regions within the region were identified which grouped counties with similar crop production characteristics. These sub-regions as shown in Figure 1 are: Western – Reeves

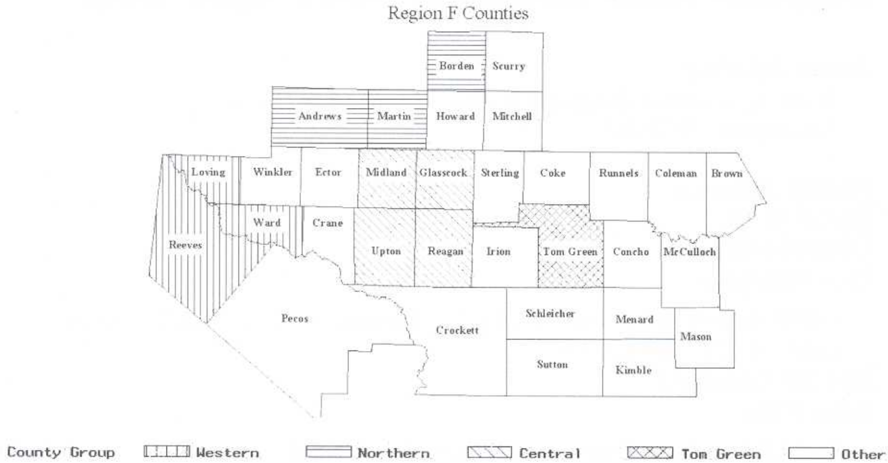

Figure 1. Region F Counties and Sub-Regions Examined for Senate Bill 1

and Loving counties; Central – Glasscock, Midland, Upton, and Reagan counties; Northern – Andrews, Borden, and Martin counties; and Tom Green County.

Water supplies within Region F come from groundwater and surface water sources. In 1997, groundwater sources accounted for 74 percent of total water use in the region. Groundwater sources include several major and minor aquifers across the region. Estimates of groundwater supplies for the period 2000 – 2050 were based on several assumptions relating to recharge and annual depletion of water held in storage. Surface water supplies are significant sources of irrigation water for several counties within the region. Seventeen major water supply reservoirs are located in Region F. However, only Red Bluff, Twin Buttes, Nasworthy and Brownwood provide significant irrigation supplies. Other surface water supplies come from run-of-the-river water rights.

The Region F Water Planning Group adopted revisions to the consensus-based projections used in the 1997 state water plan. These revisions were presented in a report titled "Revisions to Population and Water Demand Projections for Region F" dated June 1999 and prepared by Freese and Nichols, Inc. Water demand for agriculture and in particular irrigated agriculture dominates the projected regional water demand projections. Irrigation water demand is projected to account for between 69 and 74 percent of total water use in the region over the period 2000 to 2050.

The revised irrigation water demand projections were detailed in a report titled "Revisions to Irrigation Water Demand Projections for Region F" dated September 1999 and prepared by Alan Plummer Associates, Inc. The revised irrigation demand projections were based on the maximum irrigation volume for the region during the period of 1990 – 1997. Each county's maximum volume for any one year during the period was used, with the sum of each individual county's maximum demand giving the regional total. The rationale of this approach was to approximate a "dry-year" condition and also take into account the effect of increased irrigated acreage in some counties following the 1996 farm legislation.

The initial irrigation supply and demand projections for three time periods (2000, 2010, and 2020) for each county are presented in Table 1. As shown, a supply/demand imbalance is projected for 11 of the 32 Region F counties in 2000 and 10 of the 32 counties from 2010 through 2020. Several counties show extreme deficits in supply versus projected

Table 1. Initial irrigation water supply and demand projections (acre-feet of water) for Region F for 2000, 2010, and 2020.

	2000			2010			2020		
County	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference
Andrews	17,780	18,931	-1,151	18,800	18,773	27	18,800	18,616	184
Borden	953	9,662	-8,709	957	9,649	-8,692	963	9,636	-8,673
Brown	13,250	10,526	2,724	13,250	10,491	2,759	13,250	10,455	2,795
Coke	809	667	142	809	666	143	809	666	143
Coleman	2,310	1,376	934	2,310	1,364	946	2,310	1,353	957
Concho	7,082	7,082	0	7,054	7,054	0	7,026	7,026	0
Crane	337	337	0	337	337	0	337	337	0
Crockett	500	439	61	500	432	68	500	424	76
Ector	9,095	8,602	493	9,102	8,500	602	9,104	8,399	705
Glasscock	20,668	68,521	-47,853	20,663	67,979	-47,316	20,664	67,437	-46,773
Howard	4,724	4,724	0	4,671	4,671	0	4,620	4,618	2
Irion	3,331	3,296	35	3,331	3,227	104	3,331	3,157	174
Kimble	2,276	1,128	1,148	2,276	1,089	1,187	2,276	1,049	1,227
Loving	324	582	-258	324	580	-256	324	578	-254
McCulloch	3,406	2,964	442	3,406	2,928	478	3,406	2,891	515
Martin	13,501	14,221	-720	13,450	13,976	-526	13,407	13,731	-324
Mason	18,000	17,501	499	18,000	17,255	745	18,000	17,009	991
Menard	6,080	6,080	0	6,061	6,061	0	6,041	6,041	0
Midland	31,934	66,574	-34,640	33,690	66,061	-32,371	35,143	65,548	-30,405
Mitchell	2,435	2,238	197	2435	2,226	209	2,435	2,215	220
Pecos	82,464	382,458	6	81,196	81,190	6	79,927	79,921	6
Reagan	28,064	46,697	-18,633	28,060	465,937	-17,877	28,059	45,177	-17,118
Reeves	66,667	105,831	-39,164	66,667	104,942	-38,275	66,667	104,053	37,386
Runnels	9,193	7,250	1,943	9,193	7,221	1,972	9,193	7,191	2,002
Schleicher	2,000	1,807	193	2,000	1,772	228	2,000	1,737	263
Scurry	3,742	3,325	417	3,742	3,219	523	3,742	3,113	626
Sterling	980	886	94	982	851	131	983	817	166
Sutton	2,461	2,248	213	2,461	2,206	255	2,461	2,164	297
Tom Green	82,239	120,102	-37,863	82,192	119,808	-37,616	82,145	119,515	-37,370
Upton	14,681	19,824	-5,143	14,681	19,547	-4,866	14,681	19,270	-4,589
Ward	5,843	11,273	-5,430	5,849	11,136	5,287	5,933	10,999	-5,066
Winkler	1,500	1,500	0	1,500	1,500	0	1,500	1,500	0
Total	458,629	648,652	-190,023	459,949	642,648	182,699	460,037	636,643	-176,606

Table 2. Irrigated acres by crop and by county in Region F in 1997 (Texas Water Development Board).

County/Crop_	Cotton	Grain Sorghum	Wheat	Alfalfa	Forage Crops	Hay Pasture	Vegetables	Peanuts	Pecans	Vineyards	Other	County Total
Andrews	8,200	—	—	—	—	80	—	3,500	120	—	—	11,900
Borden	5,000	—	—	—	—	—	—	—	40	—	—	5,040
Brown	—	—	—	—	885	2,161	—	500	3,600	—	—	7,146
Coke	200	—	22	—	—	53	—	—	40	—	—	315
Coleman	—	—	—	—	—	871	—	—	—	—	—	871
Concho	300	1,000	900	100	230	490	—	—	—	10	—	3,030
Crane	—	—	260	—	—	—	—	—	2	2	—	264
Crockett	—	—	217	—	—	78	—	—	—	—	—	295
Ector	625	500	1,100	244	120	488	54	—	690	31	30	3,882
Glasscock	50,700	1,900	400	58	21	—	95	—	209	—	18	53,401
Howard	2,800	—	—	408	—	153	—	—	144	—	—	3,505
Irion	—	595	272	61	593	436	8	—	57	22	56	2,100
Kimble	—	—	—	—	295	787	—	—	311	—	59	1,452
Loving	—	—	—	140	—	—	—	—	—	—	—	140
McCulloch	—	—	406	—	500	454	8	216	—	—	420	2,004
Martin	6,000	—	1,112	278	—	260	—	1,800	44	—	304	9,798
Mason	310	425	1,300	—	—	490	175	2,600	8	—	595	5,903
Menard	—	—	49	300	520	1,687	—	—	138	35	820	3,549
Midland	10,300	—	948	440	4,050	12,000	160	60	500	—	40	28,498
Mitchell	1,100	—	—	217	—	—	—	—	17	—	—	1,334
Pecos	9,700	1,200	278	4,469	3,750	2,500	2,259	—	3,060	1,031	674	28,921
Reagan	27,500	680	218	50	—	—	—	—	80	—	—	28,528
Reeves	8,500	269	800	5,032	4,805	100	7,067	—	233	—	1,927	28,733
Runnels	2,800	1,043	300	—	498	352	—	—	260	180	300	5,733
Schleicher	—	—	49	—	688	—	—	—	201	—	125	1,063
Scurry	300	—	150	145	51	55	35	—	21	—	7	764
Sterling	—	—	42	—	539	—	—	—	41	—	—	622
Sutton	—	—	900	—	252	58	—	—	152	—	—	1,362
Tom Green	26,600	7,600	6,800	1,600	3,900	1,400	—	—	1,600	300	5,471	55,271
Upton	8,500	87	1,099	—	140	315	—	—	340	—	956	11,437
Ward	300	—	—	600	140	62	—	—	44	5	—	1,151
Winkler	—	—	—	—	—	—	—	—	—	—	—	0
Crop Totals	169,735	15,299	17,622	14,142	21 977	25,330	9,861	8,676	11,952	1,616	11,802	308,012

irrigation demands. These include Glasscock, Midland, Reagan, Reeves, and Tom Green counties. For example, the projected supply of irrigation water in Glasscock County was the most significant irrigated crop with 55 percent of the acres followed by hay-pasture and forage crops at 8 percent and 7 percent, respectively. Six counties (Glasscock, Midland, Pecos, Reagan, Reeves, and Tom Green) account for 72 percent of the regions irrigated acres.

METHODS

Six alternative irrigation systems were evaluated in this analysis. Irrigation systems were selected on the basis of current use in the Region or having the potential to improve water use efficiency. The alternative irrigation systems analyzed included furrow flood (FF), surge flow (SF), mid-elevation sprinkler application (MESA), low elevation spray application (LESA), low energy precision application (LEPA) and subsurface drip irrigation (DRIP). It was assumed an irrigation system was installed on a "square" quarter section of land (160 acres). Terrain and soil types were assumed to not limit the feasibility of adopting an irrigation system. Further, application efficiencies for the various irrigation technologies were taken from those identified in the water management strategy report for Region A (Almas, et al., 2000).

The adoption of advanced irrigation technologies varies significantly across counties. To establish a baseline for water demand by crop and technology, a survey was taken to determine estimates of water use by crop using furrow irrigation methods, prevalence of existing irrigation technologies by crop, and limiting factors with regard to adoption of irrigation technologies in each of the Region F counties. This information was critical in establishing a basis for identifying potential water savings from accelerated adoption of more efficient technologies. In addition, the water use data and current state of irrigation technologies allowed for the calculation of irrigation demands based on 1997 irrigated crop acres for each county. These estimated water demand levels are hereafter referred to as calculated demand. This information was provided by Texas Agricultural Extension Service specialists: Dr. Billy Warrick, Extension Agronomist, San Angelo, Dr. Bryan Unruh, Extension Agronomist, Ft. Stockton, and Dr. Juan Enciso, Extension Irrigation Specialist, Ft. Stockton.

The current adoption of irrigation technologies is shown in Table 3. Conventional furrow irrigation practices were estimated to cover 56.3 percent of the region. When combined with surge, 66.9 percent of irrigated acres are under furrow or flood irrigation. Sprinkler systems are used on 21.6 percent of irrigated acres. Drip systems have been installed on 11.5 percent of irrigated acres. A more detailed description of the Region F acres and their utilization of various irrigation technologies by crop and county for furrow, surge flow, MESA, LESA, LEPA, and drip can be found in Johnson et al. (2000).

Water management strategies to reduce irrigation demand within Region F are limited. The most feasible strategy that was considered in this analysis involved the accelerated adoption of advanced irrigation technologies, with higher water application efficiencies. The adoption of more efficient irrigation technologies such as surge flow, mid elevation sprinkler application (MESA), low elevation sprinkler application (LESA), low energy precision application (LEPA), and surface and subsurface drip would allow the application of less irrigation water, thus reducing irrigation demands. The assumed application efficiencies for furrow, surge flow, LESA, LEPA, and drip are 60 percent, 75 percent, 78 percent, 88 percent, 95 percent, and 97 percent, respectively (New, 1999).

The selection of the most feasible advanced irrigation technology for each crop within a county was based on several assumptions and constraints relating to crop type, water source, and water quality considerations. The following guidelines were used:

1. Furrow and surge acres were moved to drip or sprinkler whenever feasible.

Table 3. Estimates of irrigated acres by county using specific irrigation systems in Region F in 2000 (Warrick and Enciso).

County/System	Irrigated Area	Furrow	Surge	MESA	LESA	LEPA	Drip	% Furrow & Surge	% Sprinkler	% Drip
Andrews	11,900	5,144	0	0	5,000	1,750	36	43.0	56.7	0.3
Borden	5,040	1,040	0	2,000	2,000	0	0	20.6	79.4	0
Brown	7,146	5,528	0	1,121	497	0	0	77.4	22.6	0
Coke	315	140	0	161	14	0	0	44.4	55.6	0
Coleman	871	87	0	740	44	0	0	10.0	90.0	0
Concho	3,030	2,400	0	460	160	0	10	79.2	20.5	0.3
Crane	264	262	0	0	0	0	2	99.2	0	0.8
Crockett	295	11	0	102	182	0	0	3.7	96.3	0
Ector	3,882	2,731	0	0	602	0	549	70.4	15.5	14.1
Glasscock	53,401	33,021	0	0	0	2,535	17,845	61.8	4.7	33.5
Howard	3,505	1,655	0	0	281	1,400	169	47.2	48.0	4.8
Irion	2,100	1,649	0	429	0	0	22	78.5	20.4	1.0
Kimble	1,452	985	0	54	413	0	0	67.8	32.2	0
Loving	140	140	0	0	0	0	0	100.0	0	0
McCulloch	2,004	594	0	1,336	74	0	0	29.6	70.4	0
Martin	9,798	2,881	0	1,731	1,877	3,000	309	29.4	67.4	3.2
Mason	5,903	550	0	4,967	386	0	0	9..3	90.7	0
Menard	3,549	2,867	0	647	0	0	35	81.3	17.7	1.0
Midland	28,498	8,969	0	6,230	12,374	0	925	31.5	65.3	3.2
Mitchell	1,334	995	55	163	121	0	0	78.7	21.3	0
Pecos	28,921	9,141	14277	0	2,367	97	3,039	81.0	8.5	10.5
Reagan	28,528	24,953	0	0	0	275	3,300	87.5	1.0	11.6
Reeves	28,733	5,544	14478	0	2,750	85	5,876	69.7	9.9	20.5
runnels	5,733	5,031	232	0	290	0	180	91.8	5.1	3.1
Schleicher	1,063	977	0	86	0	0	0	91.9	8.1	0
Scurry	764	562	15	30	157	0	0	75.5	24.5	0
Sterling	622	157	0	465	0	0	0	25.2	74.8	0
Sutton	1,362	1,255	0	15	92	0	0	92.1	1.9	0
Tom Green	55,271	44,109	3,275	349	6,671	0	867	85.7	12.7	1.6
Upton	11,437	9,142	0	0	0	0	2,295	79.9	0	20.1
Ward	1,151	856	220	0	70	0	5	93.5	6.1	0.4
Winkler	0	0	0	0	0	0	0	0	0	0
Total	308,012	173,346	32552	21,086	36,422	9,142	35,464	66.9	21.6	11.5

2. Existing sprinkler acres were moved to the most efficient sprinkler technology when ever feasible.

3. Surface water supplies were assumed to remain as furrow or flood due to problems associated with the use of sprinkler or drip technologies with surface supplies. While there may be ways to make more efficient use of surface water supplies, this would involve a county-by-county assessment, which was beyond the scope of this analysis.

4. The shift of furrow to drip was considered feasible for cotton and grain sorghum.

5. Other crops such as wheat, alfalfa, peanuts, forage crops, hay-pasture, etc were shifted from furrow to the most feasible sprinkler technology.

6. Orchard and vineyard crops currently under flood irrigation were not changed to alternative technologies.

7. The application efficiency of drip and LEPA in Reeves, Ward, Loving, and Pecos counties was reduced to 93 percent and 91 percent, respectively, to allow for a flood irrigation at least once every 3 years to leach any buildup of salts in the upper soil profile.

8. No additional sprinkler acreage was included in Glasscock, Midland, Upton, and Reagan counties due to the low well yields in those counties. This would involve using multiple wells per system and was deemed unlikely.

The methodology for calculating water savings in acre-feet was to shiftacreages of furrow irrigated crops to surge flow, MESA, LESA, LEPA, or drip when an advanced technology was considered feasible. The gross irrigation application rate per acre for each crop in a given county using a furrow system with an assumed application efficiency of 60 percent was used to calculate the effective per acre water application rate. The effective application rate was then used to calculate the required equivalent irrigation application rate with an advanced irrigation technology. For example, suppose the total per acre applied irrigation water for cotton using a furrow system was 16 acre-inches. Using the 60 percent application efficiency for furrow gave an effective application rate of 9.6 acre-inches. If a drip system were used with an application efficiency of 97 percent, the resulting application rate would be 9.9 acre-inches. Therefore, the potential water savings for a shift from furrow to drip would be 6.1 acre-inches per acre.

Accelerated adoption of advanced irrigation technologies, and in particular, adoption of the most feasible advanced technologies could potentially reduce irrigation demands while maintaining the highest level of irrigated production possible. In order to examine the impact of an aggressive rate of technology adoption, it was assumed that one half of the necessary adoption of advanced irrigation technologies would take place by the year 2010, with 100 percent adoption resulting by the year 2020. Admittedly, this involves a rather ambitious level of urgency, but the primary emphasis and interest was the potential water savings available solely through efficient technologies, not the rate of adoption.

RESULTS AND DISCUSSION

Table 4 depicts the cumulative acreages and irrigation technology for Region F by decade. Initially, estimates of prevailing irrigation technology utilization in 2000 revealed 56.3 percent of the acres irrigating by furrow. After implementation of the most feasible irrigation technologies, the percentage of acres under furrow declined to only 13.3 percent and sprinkler and drip irrigated technologies increased to 31.0 and 49.4 percent, respectively.

As previously described, 1997 crop production levels were paired with prescribed irrigation water application rates necessary for typical yields to estimate the calculated irrigation demand levels for each of the Region F counties. Table 5 presents the irrigation water supply and calculated demand by decade for Region F resulting from the implementation of accelerated adoption of advanced irrigation technologies. Differences between the initial irrigation water supply and demand projections and those with calculated demand can be explained by the different assumptions underlying their derivation. The initial water demand projections were based on the highest actual water demand during

Table 4. Acres and (percent of total acreage) under various irrigation technologies for 2000, 2010, and 2020 in Region F of Texas.

Year	Furrow (%)	Surge (%)	MESA (%)	LESA (%)	LEPA (%)	Drip (%)	Total (%)
2000	173,346	32,552	21,086	36,422	9,142	35,464	308,012
	(56.3)	(10.6)	(6.8)	(11.8)	(3.0)	(11.5)	(100.0)
2010	107,226	25,957	10,549	48,842	21,613	93,825	308,012
	(34.8)	(8.4)	(3.4)	(15.9)	(7.0)	(30.5)	(100.0)
2020	41,106	19,361	0	61,272	34,086	152,186	308,012
	(13.3)	(6.3)	(0.0)	(19.9)	(11.1)	(49.4)	(100.0)

1/Irrigation technologies included: Furrow - furrow flood irrigation; Surge - surge flow irrigation; MESA - mid elevation sprinkler application; LESA - low energy precision application; and Drip - subsurface drip irrigation.

the period 1990-1997. The calculated water demand projections were based on typical irrigation applications and adjusted for the prevailing irrigation technologies existing in the county. Irrigation water supply projections were identical for both scenarios and represented the levels adopted by the Region F Water Planning Group.

A negative difference between the supply and calculated demand identifies counties with unmet irrigation demands or irrigation water deficits. Ten counties (Borden, Crane, Glasscock, Howard, Loving, Midland, Pecos, Reagan, Reeves, Tom Green) showed unmet irrigation demand in 2000. By 2020 following full adoption of the most feasible irrigation technology, five counties (Borden, Glasscock, Loving, Midland, and Reeves) continue to be faced with unmet irrigation demand. This implies that the supply-demand relationship for irrigation water in these counties cannot be balanced solely from the adoption of more efficient irrigation technologies.

Table 6 presents the estimates of water savings (acre-feet) by decade from accelerated adoption technology as well as the remaining level of unmet demand (or irrigation water deficit) for each county in Region F. With partial adoption (50%) completed by 2010, the annual water savings for the calculated demand amounted to 45,629 acre-feet. Following full adoption in 2020, these annual water savings increased to 91,250 acre-feet. Looking at counties with unmet irrigation demand, for the calculated demand scenario, 36.7 percent of the initial deficit was recovered by 2010 and 62.6 percent recovered by 2020.

To this point, this analysis has focused on the irrigation demands by counties in Region F assuming no change in acreage. Table 6 also addresses this issue as it relates to those counties within Region F with unmet irrigation demand. In addition to listing the levels of water savings and unmet demand by decade, an estimate of irrigated acres lost as a result of insufficient irrigation water availability is provided. This estimate was calculated by dividing the county's unmet irrigation demand by the average annual irrigation application rate across all crops within a county.

SUMMARY AND CONCLUSIONS

This analysis examined the potential for accelerated adoption of irrigation technologies to address irrigation water supply and demand projection imbalances in West Central Texas. This analysis provides only a preliminary estimate of lost irrigated acres because it does not allow for the possibility of shifting to crop mixes that required less irrigation. Allowing for crop mix to change would require the specification of an objective function and the use of an optimization model, which was not feasible for this analysis.

Table 5. Irrigation water supply and calculated demand (acre-feet of water) for Region F of Texas with accelerated adoption of advanced irrigation technologies, for 2000, 2010, and 2020.

County	2000			2010			2020		
	Supply	Demand	Difference	Supply	Demand	Difference	Supply	Demand	Difference
Andrews	17,780	16,303	1,477	14,534	4,266	18,800	18,800	12,766	6,034
Borden	953	5,933	-4,980	5,566	-4,609	957	963	5,198	-4,235
Brown	13,250	9,794	3,456	9,723	3,527	13,250	13,250	9,652	3,598
Coke	8 09	469	340	423	386	809	809	376	433
Coleman	2,310	1,029	1,281	981	1,329	2,310	2,310	932	1,378
Concho	7,082	3,349	3,733	3,055	3,999	7,054	7,026	2,761	4,265
Crane	337	362	-25	307	30	337	337	251	86
Crockett	500	267	233	259	241	500	500	251	249
Ector	9,095	8,167	928	7,449	1,653	9,102	9,104	6,731	2,373
Glasscock	20,668	60,735	-40,067	52,616	-31,953	20,663	20,664	44,498	-23,834
Howard	4,724	5,512	-788	5,010	-339	4,671	4,620	4,507	113
Irion	3,331	2,826	505	2,723	608	3,331	3,331	2,619	712
Kimble	2,276	1,586	690	1,583	693	2,276	2,276	1,581	695
Loving	324	583	-259	583	-259	324	324	583	-259
McCulloch	3,406	2,017	1,389	1,865	1,541	3,406	3,406	1,713	1,693
Martin	13,501	12,157	1,344	11,198	2,252	13,450	13,407	10,240	3,167
Mason	18,000	7,390	10,610	6,877	11,123	18,000	18,000	6,364	11,636
Menard	6,080	4,280	1,800	4,227	1,834	6,061	6,041	4,175	1,866
Midland	31,934	40,921	-8,987	38,541	-4,851	33,690	35,143	36,161	-1,018
Mitchell	2,435	1,923	512	1,619	816	2,435	2,435	1,316	1,119
Pecos	82,464	86,228	-3,764	81,240	-44	81,196	79,927	76,251	3,676
Reagan	28,064	36,171	-8,107	29,907	-1,847	28,060	28,059	23,643	4,416
Reeves	66,667	83,402	-16,735	79,493	-12,826	66,667	66,667	75,584	-8,917
Runnels	9,193	7,657	1,536	7,038	2,155	9,193	9,193	6,419	2,774
Schleicher	2,000	1,675	325	1,521	479	2,000	2,000	1,367	633
Scurry	3,742	1,028	2,714	893	2,849	3,742	3,742	758	2,984
Sterling	980	784	196	727	255	982	983	669	314
Sutton	2,461	2,120	341	1,878	583	2,461	2,461	1,635	826
Tom Green	82,239	100,888	-18,649	90,204	-8,012	82,192	82,145	79,521	2,624
Upton	14,681	14,453	228	12,400	2,281	14,681	14,681	10,346	4,335
Ward	5,843	4,727	1,116	4,673	1,176	5,849	5,933	4,620	1,313
Winkler	1,500	0	1,500	0	1,500	1,500	1,500	0	1,500
Total	458,629	524,736	-66,107	479,113	-19,164	459,949	460,037	433,488	26,549

Table 6. Estimates of water savings (acre-feet) from accelerated adoption of technology, Water Deficit (acre-feet), and Acres Lost in Region F of Texas for 2000, 2010 and 2020.

	2000			2010			2020		
County	Water Savings	Water Deficit	Acres Lost	Water Savings	Water Deficit	Acres Lost	Water Savings	Water Deficit	Acres Lost
Andrews	0	0	1,769	0	0	0	3,537	0	0
Borden	0	4,980	368	4,220	4,190	4,609	735	4,235	4,111
Brown	0	0	71	0	0	0	142	0	0
Coke	0	0	47	0	0	0	94	0	0
Coleman	0	0	49	0	0	0	97	0	0
Concho	0	0	294	0	0	0	588	0	0
Crane	0	25	55	18	0	0	110	0	0
Crockett	0	0	8	0	0	0	15	0	0
Ector	0	0	718	0	0	0	1,436	0	0
Glasscock	0	40,067	8,118	35,146	32,275	31,953	16,237	23,834	28,716
Howard	0	788	503	502	237	339	1,005	0	0
Irion	0	0	104	0	0	0	207	0	0
Kimble	0	0	2	0	0	0	4	0	0
Loving	0	259	0	62	62	259	0	259	62
McCulloch	0	0	152	0	0	0	305	0	0
Martin	0	0	959	0	0	0	1,917	0	0
Mason	0	0	513	0	0	0	1,026	0	0
Menard	0	0	53	0	0	0	105	0	0
Midland	0	8,987	2,380	6,241	3,593	4,851	4,760	1,018	802
Mitchell	0	0	304	0	0	0	607	0	0
Pecos	0	3,764	4,989	1,263	17	44	9,977	0	0
Reagan	0	8,107	6,264	6,383	1,759	1,847	12,529	0	0
Reeves	0	16,735	3,909	5,771	4,630	12,826	7,818	8,917	3,390
Runnels	0	0	619	0	0	0	1,239	0	0
Schleicher	0	0	154	0	0	0	309	0	0
Scurry	0	0	135	0	0	0	270	0	0
Sterling	0	0	58	0	0	0	115	0	0
Sutton	0	0	243	0	0	0	485	0	0
Tom Green	0	18,649	10,684	10,191	4,915	8,012	21,367	0	0
Upton	0	0	2,054	0	0	0	4,107	0	0
Ward	0	0	53	0	0	0	107	0	0
Winkler	0	0	0	0	0	0	0	0	0
Total	0	102,361	45,629	71,797	51,678	64,740	91,250	38,263	37,081

Some counties (Crane, Howard, Pecos, Reagan, and Tom Green) exhibited unmet demand initially in 2000, but accelerated adoption of advanced irrigation technologies appeared to offer the potential to resolve their supply/demand imbalances. These counties were likely to lose (or shift) acreage to less water intensive activities until advanced irrigation technologies could enable them to be used for more profitable enterprises. Those counties which have unmet irrigation demand throughout the study period (Borden, Glasscock, Loving, Midland, and Reeves) appear to be faced with a higher probability of losses in irrigated acreage even with adoption of advanced irrigation technologies. Even full adoption of the most efficient feasible irrigation technology was unable to resolve the irrigation water supply/demand imbalances present in these counties. Additional irrigation water supplies beyond the scope of this study would be necessary to prevent shifts or loss of acreages over time.

If the response to unmet irrigation demand results in the loss of irrigated acres, those acres will either shift to a non-irrigated alternative crop or be removed from crop production altogether. While it is difficult to predict what crops will likely go out of production, this decision will most likely be guided by the relative value of water between available cropping alternatives. In order to assess this measure for the possible alternatives, the gross marginal value of water to selected irrigated crops was calculated for the subregions exhibiting unmet irrigation demand. This addition to income from irrigation (gross marginal value of water can be compared to the investment and pumping costs to determine economic feasibility. In general, we would expect those crops with lower gross marginal values of water to exit first.

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