Projected Use of Groundwater for Irrigation in the Texas High Plains

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Projections of groundwater irrigation under alternative price conditions are computed for representative resource situations in the Texas High Plains. The rate of groundwater depletion and pumping costs are related to the level of irrigation pumpage over the period 1976-2026. The projected economic life of irrigation in this region is responsive to changing economic conditions; in particular, the rate of increase in energy prices for pumping.

Prior to the national energy crisis, the irrigation projections developed by Hughes and Harman were generally accepted as the likely pattern of irrigation decline in the Southern High Plains of Texas. The projected irrigation adjustments on farms in that study were interfaced with an input-output model to determine the decline in regional economic activity associated with groundwater depletion [Osborn and Mason]. Their results indicate that irrigated acreage in the South Plains would decline from 3.5 million acres in 1966 to 125 thousand acres in 2015 and the value of farm production would decline by 70 percent.

Other more recent studies have considered additional effects of increasing energy prices and curtailment of energy supply since the Hughes and Harman study; but they have focused on particular farm resource situations, thus omitting much of the important detail required for overall regional assessment [Casey, Lacewell, and Jones; Lacewell, Condra and Fish; Mapp and Dobbins]. For example, the recent studies do not account for effects of alternative irrigation methods, differences in irrigation response within the region, or the regional distribution of alternative water resource situations to make the results applicable to the overall region.

Previous economic studies of groundwater depletion in the High Plains appear to have followed the traditional approach to estimating the rate of depletion; that is, to treat groundwater reserves as a stock resource except for some fixed amount of annual recharge in the aquifer basin as in Burt, Cummings, and McFarland. Examples of this approach may be found in Bekure; Casey, Lacewell, and Jones; Condra and Lacewell; Hughes and Harman; and Lacewell, Condra and Fish. However, recent reports by the Texas Department of Water Resources indicate that recharge derived from irrigation recirculation is not independent of irrigation pumpage; therefore, recharge is not a fixed amount per year. Recharge also varies within the High Plains. Recharge from rainfall ranges from one-half to one inch per year on the average over the region and irrigation recirculation returns from ten to twenty percent of the pumped groundwater back to the aquifer for subsequent reuse [Texas Department of Water Resources].

The present study attempted to identify major intraregional differences in natural recharge and irrigation recirculation in developing projections of groundwater depletion for the Texas High Plains Region. Major

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differences in the use of alternative irrigation application methods and in cropping patterns were also considered in the analysis. A series of linear programming runs were made to include effects of alternative commodity and energy price scenarios on groundwater use as in Condra and Lacewell; Lacewell, Condra and Fish; and Mapp and Dobbins. Projections were identified with the regional distribution of initial water resource situations in 1976, as in the approach used by Bekure and by Hughes and Harman. Irrigation adjustments were projected for a series of five-year periods from 1976 to 2026. Changes in hydrologic parameters including well yield and pumping lift were determined at the end of each five-year period and were assumed to apply for the subsequent five-year period in projecting irrigation costs.

The Texas High Plains contains 38 million acres — nearly 22 percent of the land area in Texas [Census of Agriculture]. All of the region was included in the study except for some counties with marginal land along the Canadian River south of Subregion 2 and adjacent to the Texas Rolling Plains (Fig. 1). Resources in the study area included all cultivated land overlying a water-table thickness of 25 or more feet in 1976. Primary constraints in the linear programming model included upper limits on irrigation pumpage for each five-year period not to exceed the historical pattern of development [Wyatt], and minimum acreage levels for major crops under either dryland or irrigated production. Alternative irrigation levels were evaluated for all major crops.

Procedure for Adjusting Irrigation Cost

Changes in irrigation organization and water-table adjustments were determined for a total of 25 resource situations beginning with initial conditions in 1976 and ending in 2025 (Table 1). Five geographic subregions were delineated in the study area by major differences in soil type, irrigation application methods and crop alternatives (Figure 1). Flood application methods are the most

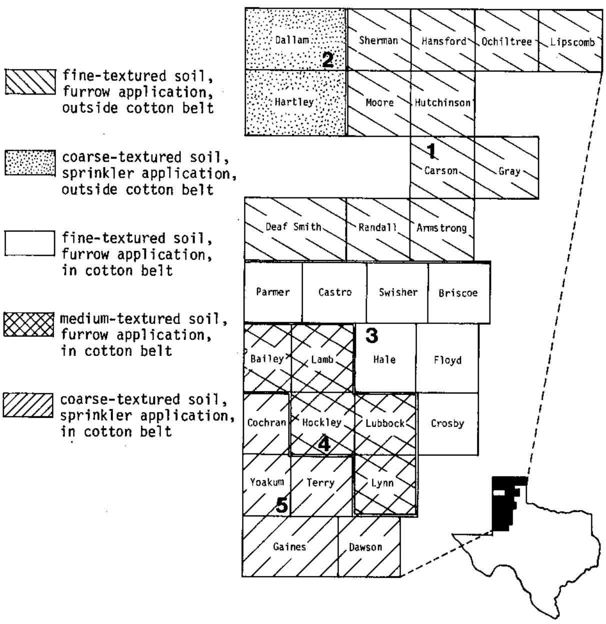

Figure 1. Map of Texas High Plains Showing Subregions with Alternative Soil Types, Alternative Irrigation Distribution Methods, and Growing Season Restrictions for Cotton.

common type of system used for fine- and medium-textured soils as in Subregions 1, 3, and 4. Sprinkler application is mandatory for coarse-textured soils as in Subregions 2 and 5.

Each subregion was divided into five groundwater resource situations.[1] Each water resource situation was defined in terms of a specific saturated thickness category and a representative well yield was determined for each category (Table 1). This procedure allowed for an intraregional shift in the distribution of water resource situations, specified in Table 1, to smaller capacity wells with increasing pumping lift as the water table declined in each subregion. Throughout the analysis, the relationship between well yield and level of saturated thickness was assumed to remain the same. As the water table declined in each subregion, the cultivated land area overlying the five saturated thickness categories in Table 1 was periodically reallocated among these categories in order to re-define the distribution of water resource situations for the subsequent period of analysis. As different parts of the aquifer declined below 25 feet saturated thickness, the overlying crop acreage was assumed to revert to dryland production.

Adjustments in pumping lift, pumping plant investment, and energy requirements for pumping in each saturated thickness category were determined at the end of each five-year period from 1976 to 2026. Water-table adjustments were made with a water balance equation which evaluated irrigation pumpage, irrigation recirculation loss, coefficients of storage, and natural recharge for each five-year period. The water-table balance equation was defined as:

$$(1) D_t = [P_t (1-I)/(CA)] - R/C$$

where: D_t = estimated amount of water-

[1]Alternative saturated-thickness categories evaluated were 25-50 feet, 50-75 feet, 75-100 feet, 100-125 feet, and 125 or more feet. A representative pumping lift was determined for each category in the base year, 1976.

TABLE 1. Initial Saturated Thickness Levels and Designated Well Categories in 1976

Saturated Thickness Interval (ft.)	Surface Acres in Subregions (1000)[a]					Well Yield (GPM)[b]	Pumping Level (ft.)[c]	Total Dynamic Head	
	1	2	3	4	5			Surface (ft.)[d]	Sprinkler (ft.)[e]
25-50	451.9	104.8	451.6	938.5	1,109.7	205	175	200	337
50-75	446.2	160.4	684.2	388.4	722.4	395	200	225	362
75-100	481.7	122.5	450.7	188.8	504.9	580	225	250	387
100-125	404.0	105.9	372.7	169.4	225.0	769	250	275	412
125-	3,601.6	1,314.7	1,469.0	534.5	68.1	955	275	300	437

[a]Total cultivated acres overlying a water table of 25 feet or more in Subregions 1,2,3,4 and 5 are 446,985; 2,345,780; 1,565,895; and 1,522, 317; respectively. Cultivated acreage in irrigation in Subregions 1,2,3,4 and 5 overlying a water table of 25 or more feet in 1976 was 1,253,257; 249,517; 1,933,780; 943,576; and 615,736; respectively. Only an additional five percent of the cultivated acreage is considered to be irrigable in the region (New).

[b]Yield estimates are based on an average drawdown ten feet less than maximum drawdown and a yield coefficient of 7.5 gallons per minute per foot of drawdown.

[c]Based on hydrologic data for these saturated thickness levels computed by the Texas Water Development Board.

[d]Based on an average requirement of 10 pounds discharge pressure at the well head for surface application.

[e]Based on an average requirement of 70 pounds discharge pressure at the well head for sprinkler application.

table decline: P_t = irrigation pumpage; I = irrigation recirculation loss coefficient; C = coefficient of storage; A = cultivated land acreage overlying the aquifer; R = natural recharge coefficient; and t = time period of analysis from 1976 to 2026 (= 1, 2, . . ., 10).

Estimates of I, C and R for equation (1) were obtained from the Texas Department of Water Resources. Values for I and R varied among subregions causing an associated difference in the projected rate of groundwater depletion relative to the level of irrigation pumpage. The water-balance equation is similar to that used in former groundwater studies except for the use of intraregional coefficients I and R [Bekure; Hughes and Harman; Mapp and Dobbins].

Criterion for Determining Groundwater Use

The decision problem in each five-year period was to select a pumpage level which maximized net crop income subject to minimum acreage restrictions for major crops on available cultivated land in each water resource situation. Upper limits on future irrigation pumpage from 1976 to 2026 allowed for continued growth in irrigation after 1976 with favorable economic conditions. The model was structured to allow for expected changes in the cropping pattern to lower water-use crops and reduced irrigation levels in response to increasing irrigation costs or a declining groundwater supply.

Net crop income was defined as a residual return to land and water. Management costs were computed at 15 percent of gross income for all crops. This cost estimate was based on reported fee schedules of professional farm managers in the area. Only part of this cost represented a return to management. The estimate also covered expenses for general overhead items such as business travel, record-keeping and communication which are not normally included in separate enterprise cost budgets. This approach to net crop income tended to narrow the absolute difference in net return between irrigated and non-irrigated crops as opposed to alternative definitions of income which assume no difference in management costs between these alternatives, as for example, in Mapp and Dobbins. Reduced returns from irrigation have the effect of shortening the economic life of irrigation.

Primary sources of data for estimating irrigation water requirements with alternative irrigation methods were area extension specialists in the region. Production costs and crop yields in each subregion were based on 1976 Texas Agricultural Extension Service Budgets, except for irrigation costs. The authors developed their own estimates of irrigation costs in cooperation with High Plains Underground Water Conservation District No. 1 and Stewart and Stevenson Services of Lubbock, Texas. Distribution costs for furrow application were included in irrigation costs for Subregions 1, 3 and 4. Distribution costs for Subregions 2 and 5 included costs for a surface booster pump, a high-pressure center-pivot sprinkler system, and application labor. An average pumping season of 2000 hours and 52 percent efficiency were assumed in estimating pumping costs [Agricultural Engineering Department]. Representative prices in 1976 were assumed for all production inputs, except natural gas.

Future price scenarios assumed for natural gas were: (1) a constant price of \$1.36 per thousand cubic feet (mcf), and (2) increasing prices per mcf of \$1.36 for 1976-80, \$2.45 for 1981-85, \$3.53 for 1986-90, \$3.87 for 1991-95, \$4.56 for 1996-2000, \$5.33 for 2001-05 \$6.18 for 2006-10, \$7.17 for 2011-15, \$8.32 for 2016-20, and \$9.65 for 2021-25. Price projections to 2001 were obtained from a recent 25-year projection by the Texas Governor's Energy Advisory Council. A linear extrapolation was used to project prices beyond 2001. Prices for electricity were estimated to increase at the same rate as natural gas prices in the 25-year projection by the Texas Governor's Energy Advisory Council.

Two grain price levels (intermediate and high) were utilized in the analysis. Cotton and minor crops were evaluated at an intermediate price level.[2] Intermediate grain prices were assumed to be the approximate average market levels for 1976 and high prices were assumed to be the highest market levels for 1976. An average cotton price for the July-August 1976 market period was used.

Results

Irrigation costs also were projected for five-year intervals from 1976 to 2026 (Table 2). Initial costs per acre-inch ranged from \$2.13 to \$2.99 in subregions with furrow application and from \$3.50 to \$4.18 with high-pressure sprinkler application. The differences in cost per acre-inch are attributed to higher total dynamic head requirements with sprinkler application and to additional investment cost in center-pivot systems compared with furrow applications. Irrigation costs varied for alternative water resource situations in each subregion due to economies of size in pumping plant investment. Wells with relatively high yield tended to have the lowest pumping cost per acre-inch throughout the analysis. Upper limit irrigation costs for most major crops were projected to occur in the 2021-2025 period with a constant natural gas price and in the 1991-1995 period with an increasing natural gas price. Additional irrigation costs could be sustained for some minor crops with limited irrigation application levels. Sunflowers is an example.

Grain corn, alfalfa and wheat were the first irrigated crops removed from production as a result of increasing irrigation cost in the cropping pattern analysis. Irrigation of all remaining major crops terminated after 2025 with a constant natural gas price of \$1.36 per mcf except for some grain sorghum in Subregion 1 and cotton in Subregions 3 and 4. Irrigation terminated after 1995 for cotton and all grains except sorghum as a result of an increasing natural gas price. Irrigation continued for another five-year period for sorghum at the higher price level.[3] In general, the economic life of irrigation was estimated to be 10 to 15 years less in subregions requiring high-pressure sprinkler application than in subregions with furrow application.

Annual irrigation pumpage was reduced from 5 million acre-feet in 1976 to 1.2 million acre-feet in 2025 with intermediate level grain prices and a constant natural gas price of \$1.36 per mcf. Annual pumpage was initially 5.8 million and 5 million acre-feet, respectively, with high and intermediate level grain prices and a price of \$1.36 per mcf for natural gas. After 1991, annual irrigation pumpage was similar for both grain price levels under rising prices for natural gas.

Projected groundwater depletion rates in Subregion 1 are shown in Table 3 for the combination of high grain prices and an increasing natural gas price. Historical rates of groundwater depletion in the region have ranged from 0.95 to 3.53 feet per year (Texas Department of Water Resources). Use of the water-table balance equation (equation 1) resulted in a relatively high projected annual rate of decline for Subregion 1 (up to 4.3 feet per year) from 1976 to 1986 (Table 3). After 1986, the rate of decline tended to be relatively low and irrigation terminated in 2006 for all saturated thickness categories. Projections of water-table decline were similar for other subregions with high grain prices. Rates of decline were less during the first three 5-year periods with intermediate

[2]Intermediate prices used in the analysis were \$2.24 per bushel for grain corn, \$0.40 per pound for cotton lint, \$90.00 per ton for cotton seed, \$3.75 per hundred weight for grain sorghum, \$3.17 per bushel for wheat, \$45.00 per acre for irrigated wheat grazing, \$27.00 per acre for dryland wheat grazing, \$5.00 per bushel for soybeans, \$15.00 per hundred weight for field peas, \$10.00 per hundred weight for sunflowers and \$40.00 per ton for alfalfa priced in the field. High prices used were \$2.70 per bushel for grain corn, \$4.50 per hundred weight for grain sorghum, \$3.75 per bushel for wheat and the same prices as above for other commodities.

[3]The cotton price used was based on the approximate market level in July and August of 1976. In retrospect, this price may be low relative to grain prices which could cause the irrigation and output projections for cotton to be understated.

TABLE 2. Projected Irrigation Costs Per Acre-Inch in the Texas High Plains with Alternative Grain Prices, Distribution Methods and Natural Gas Prices, 1976-2025

Time Period	Intermediate Grain Prices				High Grain Prices	
	Furrow Application[a]		Sprinkler Application[b]		Furrow Application[a]	Sprinkler Application[b]
	Constant Gas Price[c]	Increasing Gas Price[d]	Constant Gas Price[c]	Increasing Gas Price[d]	Increasing Gas Price[d]	Increasing Gas Price[d]
1976-1980:	$2.13-$2.99	$2.13-$2.99	$3.50-$4.18	$3.50-$4.18	$2.13-$2.99	$3.50-$4.18
1981-1985:	2.22- 3.24	3.01- 3.84	3.50- 4.43	4.55- 5.23	2.89- 3.86	4.58- 5.25
1986-1990:	2.35- 3.51	3.86- 4.54	3.61- 4.45	5.53- 5.91	3.75- 4.89	5.54- 6.30
1991-1995:	2.39- 3.77	4.29- 4.68	3.61- 4.69	6.15- 6.33	4.13- 5.15	6.04- 6.51
1996-2000:	2.42- 3.80	4.83- 5.20	3.74- 4.71	6.82- 6.94	5.18- 5.68	6.65- 7.08
2001-2005:	2.46- 3.80	5.13- 5.77	3.77- 4.72	7.57- 7.71	5.92- 6.06	n.a.[e]
2006-2010:	2.52- 3.80	6.11- 6.61	3.90- 4.72	n.a.[e]	6.71	n.a.[e]
2011-2015:	2.55- 4.00	6.11- 6.91	3.90- 4.75	n.a.[e]	7.45	n.a.[e]
2016-2020:	2.59- 4.04	n.a.[e]	3.90- 4.78	n.a.[e]	n.a.[e]	n.a.[e]
2021-2025:	2.63- 4.26	n.a.[e]	3.93- 4.82	n.a.[e]	n.a.[e]	n.a.[e]

[a]Applicable to Subregions 1, 3 and 4.

[b]Applicable to Subregions 2 and 5.

[c]A price of $1.36 per MCF from 1976 to 2026.

[d]Price of natural gas per MCF was assumed to be $1.36 for 1976-1980, $2.45 for 1981-1985, $3.53 for 1986-1990, $3.87 for 1991-1995, $4.56 for 1996-2000, $5.33 for 2001-2005, $6.18 for 2006-2010, $7.17 for 2011-2015, $8.32 for 2016-2020, and $9.65 for 2021-2025.

[e]Non applicable due to termination of all irrigation.

TABLE 3. Projected Annual Water-Table Depletion Rates for Subregion 1 with High Grain Prices and Increasing Natural Gas Prices, 1976 to 2026

Saturated Thickness (ft.)	Initial Cultivated Acreage Overlying the Water Table (1000)	Annual Rate of Water-Table Decline (ft.)						
		1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10
25-50	246.4	4.2	3.3	1.1	1.1	1.1	0	0
50-75	244.5	4.6	4.6	3.7	1.1	1.1	0.	0
75-100	255.3	4.6	4.3	3.7	1.2	1.2	1.2	0
100-125	214.5	4.3	4.3	4.4	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]
125-150	247.9	4.2	4.2	0.8	0.8	0.8	0.8	0
150-175	286.4	4.2	4.2	0.8	0.8	0.8	0.8	0
175-200	356.1	4.2	4.2	0.8	0.8	0.8	0.8	0
200-225	341.2	4.2	4.2	0.8	0.8	0.8	0.8	0
225-250	261.2	4.2	4.2	0.8	0.8	0.8	0.8	0
250-275	191.9	4.2	4.2	0.8	0.8	0.8	0.8	0
275-300	131.1	4.2	4.2	0.8	0.8	0.8	0.8	0
300-325	78.1	4.2	4.2	0.8	0.8	0.8	0.8	0
325-350	69.5	4.2	4.2	0.8	0.8	0.8	0.8	0
350-375	41.3	4.2	4.2	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]
375-400	41.1	4.2	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]	n.a.[a]

[a]Not applicable due to estimated depletion of the water table beyond the limits of this saturated thickness category.

grain prices and an increasing natural gas price.

Crop Output and Income Projections

Total grain sorghum and cotton output in the study region declined by 61 and 33 percent, respectively, from 1976 to 2026 with intermediate grain prices and an assumed constant price of $1.36 per mcf for natural gas. Wheat output increased 23 percent as a result of a shift in the cropping pattern associated with dryland production. Crop output projections with intermediate grain prices and an increasing natural gas price indicated that wheat output would increase 44 percent, and output of grain sorghum and cotton would decline by 70 and 33 percent, respectively. Comparable crop output projections were obtained for high grain prices and an increasing natural gas price.

Annual net crop income in the 32-county study region was projected to decline from $277 million in 1976 to $186 million in 2025 for the case of continued intermediate grain prices and a constant natural gas price (Table 4). Irrigated acreage declined from 4.2 million to 1.1 million for the projected time interval. There were 4.6 million acres in dryland production overlying a water table of at least 25 feet saturated thickness in 1976. In 2025 there were 7.6 million acres in dryland production projected for this price scenario. The groundwater supply for irrigation was depleted when 4.6 million acres were used in dryland production. The remaining 3 million acres were diverted to dryland production because of excessive irrigation costs.

For intermediate grain prices and an increasing natural gas price, annual net crop income in the region declined from $277 million in 1976 to $164 million in 2025. Irrigation was less profitable with an increasing natural gas price and less groundwater depletion was projected than in the case of a constant natural gas price.

With the increasing price scenario, there were 6.9 million acres in dryland production with available groundwater supply and 1.8 million acres in dryland production with a depleted groundwater supply when irrigation terminated.

For high grain prices and an increasing natural gas price, annual net crop income declined from $391 million in 1976 to $224 million in 2025. Prior to 1991, the projected annual pumpage was greater than in the case of intermediate grain prices which resulted in more depletion of the groundwater supply when irrigation terminated. The area of the aquifer depleted was 3.3 million acres compared with 1.8 million acres under intermediate grain price conditions (Table 4).

Conclusions

Projections of the economic life of irrigation are of special interest to agricultural regions such as the Texas High Plains which have an exhaustible groundwater supply. The eventual decline in irrigation within this region has important implications at both the state and national level, but it is difficult to predict exactly when irrigation will finally terminate. Projections will continue to be modified with changing economic conditions, advances in irrigation technology and additional information on the actual dynamics of water-table depletion in the Ogallala Aquifer.

This study attempted to distinguish major intraregional differences in cropping patterns, irrigation application methods, natural recharge and irrigation recirculation in predicting the future use of groundwater for irrigation. Several key assumptions were employed in the analysis: the continued use of current irrigation technology to 2026, the use of natural gas as a proxy for all types of energy used in pump irrigation, and confinement of future irrigation development to cultivated land available in 1976. Likely adjustments to increased irrigation costs include the use of alternative forms of energy such as solar and wind power, changes in technology to increase the efficiency of irrigation pumping plants and distribution systems, and improved crop production programs. These adjustments would modify the projections for groundwater use in the region.

TABLE 4. Projected Annual Regional Net Crop Income and Land Use With Increasing Natural Gas Prices[a] and Alternative Grain Prices, Texas High Plains, 1976-2025

Period of Production	Annual Net Crop Income (mil.)		Acres Irrigated in Aquifer Area (mil.)[b]		Dryland Crop Acres in Aquifer Area (mil.)[b]		Acres Cultivated With Depleted Groundwater (mil.)	
	Intermediate	High	Intermediate	High	Intermediate	High	Intermediate	High
1976-81:	$277.0	$391.0	4.2	4.2	4.7	4.7	0	0
1981-86:	217.8	317.5	3.5	3.7	4.9	4.7	0.5	0.5
1986-91:	177.9	259.7	2.2	2.2	5.5	4.3	1.2	2.4
1991-96:	175.3	241.9	1.5	1.2	5.5	4.8	1.8	3.1
1996-2001:	170.7	230.0	0.7	0.5	6.3	5.1	1.8	3.1
2001-06:	167.3	226.2	0.5	0.4	6.5	5.3	1.8	3.3
2006-11:	165.1	224.9	0.3	0.1	6.7	5.4	1.8	3.3
2011-16:	164.7	224.0	0.1	0.1	6.9	5.4	1.8	3.3
2016-21:	164.2	223.6	0	0	6.9	5.5	1.8	3.3
2021-26:	164.2	223.6	0	0	6.9	5.5	1.8	3.3

[a]Natural gas prices per Mcf were assumed to be $1.36 for 1976-80, $2.45 for 1981-85, $3.53 for 1986-90, $3.87 for 1991-95, $4.56 for 1996-2000, $5.33 for 2001-05, $6.18 for 2006-10, $7.17 for 2001-15, $8.32 for 2016-20, and $9.65 for 2021-25 on the basis of recent projections by the Texas Governor's Energy Advisory Council.

[b]The aquifer area was defined to be the cultivated land area in 1976 overlying a water table of at least 25 feet saturated thickness. Crop income from cultivated acres in the aquifer area was assumed to be derived from dryland production when the water table became depleted below 25 feet in thickness.

One of the significant findings was that irrigation would decline before groundwater reserves were depleted. This result occurred for all price scenarios assumed for grains and natural gas. Alternative grain prices caused variation in the level of irrigation pumpage and groundwater depletion from 1976 to 1991, but had little effect after 1991.

Projected irrigation adjustments were responsive to increases in the price of natural gas. Irrigated acreage declined to 1.2 million in the 1991-1996 period when the price of natural gas increased to $3.87 per mcf under conditions of both high and intermediate grain prices. With a constant natural gas price of $1.36 per mcf and intermediate grain prices, irrigated acreage did not decline to this level until the 2021-2026 period. The decline in irrigated acreage to 1.2 million marked the end of irrigation for most major crops. Only limited irrigation of minor crops continued beyond 2026 for all subregions in the study. The economic life of irrigation was ten to fifteen years longer in subregions with furrow application than in subregions with high-pressure sprinkler application.

Annual net crop income in the study region declined by 33 to 43 percent from 1976 to 2026 under the alternative price scenarios. Differences in management costs for irrigated and dryland production reduced the estimated difference in net crop income between these production alternatives, in contrast to other possible definitions of income which do not treat management as an input cost. Thus, the estimated economic life of irrigation in this study was reduced as a result of the definition used for net income.

Reversion to dryland production brought changes in cropping patterns and in aggregate crop output. Grain sorghum output declined by 61 to 70 percent in the 32-county region. Cotton output declined 33 percent with the assumed 1976 price for cotton. On the other hand, wheat output increased by 23 to 44 percent with the shift to dryland production.

These projections of groundwater depletion were influenced by the use of intraregional coefficients for natural recharge and irrigation recirculation in the water-table balance equation. Including these relationships tended to dampen the projected depletion rate compared with other projection methods which have not included these relationships [Bekure; Hughes and Harman; and Mapp and Dobbins]. Use of this modified approach provided estimates of groundwater depletion which were similar to historic rates of depletion in the Texas High Plains. For example, the 1960-72 average water table decline in Parmer County was 3.9 feet for wells with a saturated thickness of 180 to 200 feet [Texas Department of Water Resources]. The projected rate of depletion in Table 3 for this range of saturated thickness is 4.2 feet per year from 1976 to 1986.

Several policy implications arise from these results. The economic life of groundwater supply for irrigation may be extended by improved pumping plant and distribution efficiency, by development of economical sources of energy for irrigation pumping, and by alternative production practices to reduce dependency on groundwater use. A significant amount of groundwater remained available in the region when irrigation was projected to terminate. This groundwater could be utilized for higher-valued uses such as industry or for future irrigation use under improved cost-price relationships. However, the immediate outlook is that the process of adjustment in agriculture will be fairly rapid in the next few years in response to increasing energy prices for irrigation pumping. Various agriculture-related interests in the region need to plan for this adjustment, including changes in farm organization, likely population migration, reduced use of soil services, and decreased agricultural production in the region. Similar adjustments also will occur in other agricultural regions that are experiencing declining groundwater supplies for irrigation.

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