REGIONAL IMPACT OF URBAN WATER USE ON IRRIGATED AGRICULTURE

John G. Lee, Ronald D. Lacewell, Teofilo Ozuna, Jr., and Lonnie L. Jones

Abstract

Linear programming and regional input-output models were applied to estimate the impacts of increased pumping costs for irrigated agriculture due to groundwater depletion principally caused by the expanding urban area of San Antonio, Texas. A biophysical simulator was used to estimate linear programming coefficients of crop yield by irrigation level and timing. The results indicate significant local (county) economic impacts from groundwater mining but insignificant regional impacts. A major improvement in irrigation efficiency would be required to offset the increased pumping costs and reduced water availability associated with increased lifts due to urban expansion.

Key words: biophysical simulation, groundwater, regional input-output.

Considerable research efforts have focused on the conversion of prime agricultural land to urban uses (Ramsey and Corty; Burnham; Schmid). Less attention has been given to other natural resources for which urban and rural users simultaneously compete. One such resource is groundwater. Groundwater in Texas may be purchased either in conjunction with surface rights or as a separable right. Under the predominant conjunctive rights system, the overlying land provides an easement for extraction whereby ownership to individual units of groundwater is assigned as the water is removed. In an unconfined aquifer, however, groundwater may resemble a fugitive resource if it moves rapidly beneath the land surface.

There are aquifers in Texas, such as the Edwards, which are characterized by relatively large rates of recharge and rapid groundwater movement. A market in water rights has not evolved due largely to the fugitive nature of groundwater in these aquifers. This means market development for the Edwards and similar aquifers has been impeded, in part, due to the lack of exclusion.

The lack of exclusion coupled with high rates of recharge and groundwater movement can lead to an externality. Lin defines an externality as a situation in which the private economy lacks sufficient incentive to create a market in some good and the nonexistence of this market results in losses in Pareto efficiency. Randall indicates that the cost of exclusion for certain groundwater pools could be so large as to prohibit the establishment of transferable groundwater rights. In addition, Randall points out that some peculiarities in the physical nature of the resource itself (e.g., large rates of groundwater movement) can lead to high transaction costs which inhibit trade. Specifically, the transaction cost of monitoring recharge and withdrawals may be prohibitive under the current institutional structure. A potential externality can exist in the case of the Edwards Aquifer because one user can reduce the static groundwater level, thus reducing well yield and increasing lift and pumping cost for other users.

Uvalde County, commonly referred to as the Winter Garden, provides a unique area in which to examine this potential externality. This county overlays the Edwards Aquifer. Irrigated agriculture is a major sector of the county's economy. Urban expansion in San Antonio affects availability and cost of water to the agricultural users in Uvalde County. The objectives of this study were to estimate how projected future groundwater withdrawal rates of San Antonio will impact irri-

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gated agriculture in Uvalde County, estimate the economic impacts, and examine the policy implications for the region and state. To address these objectives, a linear programming model of agricultural production in Uvalde County was developed to evaluate agricultural adjustments to declining groundwater availability. Economic impacts were estimated via a regional input-output model using solutions from the linear programming model.

STUDY AREA

The Edwards Aquifer covers several Texas counties with the primary region comprised of Bexar, Comal, Hays, Medina, and Uvalde counties. There is a total of 5,376 square miles in the five counties with 23 percent in Bexar and 29 percent in Uvalde. Of a total 1980 population of 1.1 million, 988,000 were in Bexar County compared to 22,441 in Uvalde County (Kingston). Uvalde and Medina counties are agricultural, Bexar County—the location of San Antonio—is urban, while Comal and Hays counties are dominated by springflow recreational and manufacturing activities. San Antonio, the major center of economic activity in the region, exerts a strong economic influence on all of the counties in the study area with the exception of Uvalde.[1]

Annual recharge to the Edwards Aquifer averages approximately 608,000 acre-feet with recharge zones located throughout the region. Groundwater flows from the southwest to the northeast, traveling beneath irrigated land in Uvalde County to San Antonio in Bexar County and on to Hays and Comal Counties. Springflow or spring discharge has previously averaged 360,000 acre-feet per year. With an increase in pumping, the rate of spring discharge will be reduced and could be disrupted completely. Current pumpage rates for the entire aquifer are estimated at over 400,000 acre-feet per year (CH2M Hill).

Through the unusually wet years of the 1970s, the Edwards Aquifer built up a reservoir of water. This permitted pumping and springflow to exceed recharge in the short-run. After the water level had been drawn down, natural springflow fed by the Edwards was projected to decline to 135,000 acre-feet per year with an annual pumpage rate of 450,000 acre-feet. Further increases in pumpage would result in even greater reductions in springflow. The springflow represents the headwaters of one river (San Marcos River) and contributes to significant recreational activity in Hays and Comal Counties. Reduced springflow affects water quality, recreational activity, and riverflow to downstream users.

In the study area, the Edwards Aquifer includes 400 to 700 feet of faulted limestone and dolomite which contribute to the aquifer's excellent transmissive characteristics. There is an extensive honey-combed network of voids and interconnected cavities throughout the freshwater portion of the aquifer. Transmissivity of the Edwards exceeds 20 million gallons per day per foot.[2] By contrast, transmissivity of the Ogallala in the Texas High Plains is 400 gallons per day per foot (Raynor). There is relatively rapid movement of water into and through the Edwards Aquifer resulting in a situation whereby users in one area can significantly affect users in other areas.

Two major users of groundwater from the Edwards Aquifer are farmers who irrigate and the city of San Antonio. The study area receives on average 24 inches of annual rainfall. This level of precipitation is sufficient for dryland crop production. Irrigation, however, doubles yields above dryland on row crops and wheat and allows vegetable production. There are 116,250 irrigated acres in this region, with 55,750 of these in Uvalde County (Texas Crop and Livestock Reporting Service). To estimate the impact of greater pumpage rates by the city of San Antonio on irrigated agriculture and the local economy, we selected Uvalde County, since it was not close to San Antonio and for the most part is agriculturally based. Approximately 79 percent of the irrigated acres in Uvalde County are gravity flow systems, with the remaining 21 percent being sprinkler systems (Texas Crop and Livestock Reporting Service).

The Edwards Aquifer provides the total public water supply for San Antonio. The capacities of wells operated by San Antonio are among the largest in the world, with single well capacities in excess of 16,000 gallons per minute (U.S. Geological Survey). As San Antonio withdraws more groundwater to sup-

[1]The economy of Uvalde County is more dependent on irrigated agriculture than are the economies of the others. Medina, Comal, and Hays Counties have additional interdependences beyond groundwater to the vast urban economy of San Antonio. These additional interdependencies include employment, health services, wholesale and retail trade, etc.

[2]High-yielding aquifers typically are classified as having a transmissivity of over 100,000 gallons per day per foot (CH2M Hill).

port its economic growth, the depth to water increases which increases pumping lift and pumping costs. An increase in water cost reduces irrigation net returns relative to lower irrigation costs regardless of crop prices. With constant or lower crop prices, an increase in irrigation costs may result in farmer adjustments to other crops, less irrigation, or even reversion to dryland production. This adjustment depends on the magnitude of increase in the pumping cost and the value of crops produced.

METHODOLOGY

To evaluate the impact of alternative groundwater scenarios on agriculture, we developed a linear programming model to reflect agricultural production in Uvalde County. The objective function of the linear programming model was maximization of net returns to land, labor, and water. Since one objective of this study was to assess the impact on crop production of aquifer drawdown by San Antonio, information on crop yield by quantity and timing of irrigation water was needed. Primary data for the county on irrigated crop yield by quantity and timing of water were not available. A daily crop growth simulation model was used to estimate yield by crop, irrigation level, and irrigation timing in a fashion similar to Mapp and Eidman, and Boggess and Amerling. Musser and Tew provide an assessment of the use and potential of biophysical simulation in the area of production economics.

A daily plant growth simulation model known as the Erosion Productivity Impact Calculator (EPIC) was used to estimate crop yields by irrigation level and timing on a Uvalde soil type (Williams et al.). This is the predominant soil type for crop production in the area (U.S. Department of Agriculture). Irrigation timing and amounts as well as tillage information for the simulation model were obtained from crop enterprise budgets of the Texas Agricultural Extension Service and validated by experts in the area (Pena).

The components of EPIC included weather simulation, hydrology, erosion-sedimentation, nutrient cycling, tillage, soil temperature, plant growth, economic accounting, and plant environment. The crops simulated included cotton, wheat, grain sorghum, and corn. Yields predicted by EPIC for each crop by irrigation timing and amount were used as coefficients in the linear programming model. These represent points on production functions which become activities in the linear programming model. Fresh-market spinach, carrots, cantaloupe, and onions were incorporated into the model with production data based on published crop budgets in the region (Pena).

The Uvalde County linear programming model expressed in matrix form is as follows:

$$
(1)\quad \begin{array}{lrrrrl}
\max & -CX & & +HZ & & \\
\text{subject to:} & AX & & & & \leq b \\
 & DX & -EW & & & \leq 0 \\
 & & W & & & \leq V \\
 & -BX & & +Z & & \leq 0 \\
 & & & +Z & -G & \leq 0,
\end{array}
$$

where:

- X = vector of crop production alternatives,
- C = vector of variable cost by crop alternative,
- Z = vector sum by crop of output,
- H = vector of crop prices,
- A = vector of variable input or resource requirements per unit of each crop alternative,
- D = vector of plant irrigation water requirements per acre of each crop alternative,
- W = vector of water use by crop for each two-week period,
- B = vector of crop yield per acre,
- E = vector of pumping efficiency,
- V = vector of pumping capacities by time period,
- G = vector of accounting activities for irrigated and dryland gross revenue, and
- b = vector of resource endowments.

The linear programming model contained 49 crop production alternatives. These include alternative irrigation levels and application times for cotton, wheat, grain sorghum, and corn; irrigated fresh-market vegetable alternatives; and dryland cotton, grain sorghum, wheat, and hay. Activities were included to allow accounting of gross revenue from irrigated and dryland crop production for subsequent use in the regional input-output model.

Irrigation application efficiency for 1984 was assumed to be 60 percent (Pena; Wyatt). The amount of water pumped for irrigation to meet plant requirements allowed for a 40 percent loss to evaporation, deep percolation, and runoff.[3] Transformation variables were used to convert plant water requirements to total water pumped. Water availability in each two-week time period of the growing season was a function of well yield and potential pumping days.

Maps illustrating irrigated acres as well as basic aquifer characteristics were used to establish three different groundwater situations for Uvalde County (Texas Department of Water Resources).These are representative of the heterogeneity of the Edwards Aquifer for irrigated land in Uvalde County. The annual quantities of surface water, groundwater, and associated lift were estimated by the Texas Department of Water Resources for 1984 and each decade to 2040 as shown in Table 1. The selection of 2040 was to provide for long-term planning. We used the 1984 and 2040 estimates to measure changes in aquifer conditions.

TABLE 1: ESTIMATED PUMPING LIFTS AND QUANTITIES FOR AGRICULTURE IN 1984 AND 2040 ASSUMING CONTINUATION OF PRESENT WATER POLICIES, UVALDE COUNTY, TEXAS

	1984			2040		
Water* source	Water (acre-feet)	Lift (feet)	Cost Per acre-inch (dollars)	Water (acre-feet)	Lift (feet)	Cost Per acre-inch (dollars)
Ground1	21,385	53	1.60	11,317	96	2.30
Ground2	34,528	153	3.23	18,433	248	4.82
Ground3	18,340	114	2.61	9,791	223	4.40
Surface	1,566	0	.73	1,582	0	.73

Source: Texas Department of Water Resources.

* The three sources of groundwater were developed to reflect the spatial heterogeneity of cost and availability of groundwater from the Edwards Aquifer.

The amount of water in each groundwater class in Table 1 was a function of projected withdrawals for alternative uses. These uses included irrigated agriculture but consisted primarily of urban demand created by the expansion of San Antonio. Projected increased pumpage by irrigated agriculture and San Antonio resulted in an increasing lift and declining well yields in Uvalde County. Application of a groundwater model for the Edwards Aquifer by the Texas Department of Water Resources provided the resulting estimates of pumpage rates.

The costs of pumping water for irrigation from each of the water sources, as shown in Table 1, were calculated using equations from Greenwalt and May. The average pressure of irrigation systems in Uvalde County is 19 pounds per square inch (PSI). Pressure was converted to lift for groundwater and surface water, based on 2.41 PSI equal to one foot of lift. For surface water, energy was required to develop pressure for the irrigation distribution system at a cost of $0.73 per acre inch. All values were calculated in 1984 nominal dollars; thus, there is no consideration of inflation or relative changes in crop and/or input prices.

The linear programming model was applied under four scenarios. The first scenario established the 1984 base and reflected current resource availability, production practices, and efficiencies. The second scenario was comparable to the first except total irrigation water from all four sources was set at zero. The difference in the objective function values beween the first and second scenarios is an estimate of the direct value of net returns of irrigation to the agricultural sector of Uvalde County's economy. In addition, gross revenue from each case could be used in the regional input-output model to reflect direct, indirect, and induced effects of irrigation.

The third scenario was comparable to the first, except the cost of water from each irrigation source was updated to reflect conditions (lifts) as they related to projected groundwater mining in 2040. Application efficiency was assumed to be 100 percent to reflect an approximation of the maximum attainable application efficiency through the total adoption of improved irrigation equipment. The plant requirement included some plant-specific deep percolation and evapotranspiration losses. There is not a salinity problem on irrigated land in the area at present. It is acknowledged, however, that using 100 percent application efficiency could potentially result in salt intensification and could represent one limitation of this assumption.

It was assumed that over the 56 years from 1984 to 2040, irrigation equipment requiring replacement was replaced with high efficiency equipment and the annual fixed costs required to attain greater efficiency were comparable to current levels. Due to the gradual change in pumping lift over time and difficulty of projecting the rate of adoption of water conserving technology, the analysis moved directly to 2040 as opposed to recursively solving the model from 1984 to 2040.

[3]Application efficiency indicates the fraction of applied water stored within the root zone that is potentially accessible for evapotranspiration (American Society of Civil Engineers).

The fourth scenario is similar to the third except that irrigation application efficiency was maintained at the 1984 level of 60 percent under 2040 groundwater conditions. The difference between the third and fourth scenarios provides an estimate of potential direct benefits from improving irrigation application efficiency to a maximum of 100 percent. It is conceivable that a greater investment would be required to achieve 100 percent efficiency. The difference in net returns for 60 and 100 percent efficiency provides a breakeven amortized annual value that could be expended for new equipment beyond the fixed costs incorporated in the model.

One objective of this study was to assess the impact of decreasing groundwater availability for agriculture on a five-county regional economy. The economic activity of this region is diverse, including the urban economy of Bexar County, recreation activities in Hays and Comal Counties, and agricultural production in Uvalde and Medina Counties.

The location quotient technique, based on the Texas Input-Output Primary Data Model (Wright et al.), was used to develop an input-output model for the study area. The Texas Input-Output Model is based on 1979 data. It has 34 processing sectors, 7 final demand sectors, and 6 final payments sectors.

Sector control totals were developed by the Texas Department of Water Resources using county and state wage information available from the Texas Employment Commission. Control totals are defined as the total value of output attributed to a particular sector of the state or regional economy. The control totals were estimated as follows:

$$(2) \qquad CT_i^s \cdot \frac{W_i^{FC}}{W_i^s} = CT_i^{FC},$$

where:

CT_i^s = control total for sector i at the state level,

W_i^{FC} = wages paid in sector i within the five-county region,

W_i^s = wages paid in sector i within the state, and

CT_i^{FC} = control total in sector i at the five-county level.

This procedure assumes that within any sector the local or five-county wage rate is the same as for the state. A comparison of wage rates for the study area and the state indicates a difference of −4 percent for retail trade and −8 percent for general service (U.S. Department of Commerce). These two sectors account for 54 percent of non-farm, private employment in the study area. Across all non-farm sectors, the difference between the study area and the state was less than 10 percent.

The input-output structure for the five-county study region was estimated using the computerized location quotient model reported in Mustafa and Jones. This study-area model was aggregated to 34 processing sectors, two final demand sectors, and two final payment sectors. The model provided estimates of transaction tables, technical coefficients, and interdependence coefficients for the study area and final demand, income, and employment multipliers for each sector of the economy.

The input-output model for the study area was of the Leontief structure, which can be expressed in matrix form as:

$$(3) \qquad Y = (I-K)^{-1}(FD),$$

where:

Y = 34×1 vector of total output by sectors,

$(I-K)^{-1}$ = 34×34 matrix of interdependence coefficients, and

FD = 34×1 vector of final demand by sector.

To estimate the impact of a reduction in irrigated output on the Uvalde County economy versus the five-county regional economy, interdependence coefficients for irrigated agriculture were applied. Each sector affected by irrigated agriculture was classified as having either a principally local impact (Uvalde County in this case) or a regional impact (affecting all the counties, but principally San Antonio). The classification of each sector was based on employment statistics, interviews, and subjective judgment. The interdependence coefficients were applied to the change in gross revenue estimated from the linear programming model to adjust the total output vector of the regional input-output model.

RESULTS

For the analysis, impacts of declining groundwater on agriculture in Uvalde County were considered from three perspectives: (1) the 1984 base condition compared to no irrigation, (2) the base compared to 2040 groundwater conditions but with improved application efficiency, and (3) the base compared to 2040 groundwater conditions but with 1984 application efficiency. Estimated net and gross returns for each scenario are presented in Table 2. No irrigation would impact farmer net returns (returns above variable costs) more than gross returns. Under current conditions, irrigation accounts for $6.0 million in net returns. Without irrigation in 1984, net returns on cropland in the county would decline by 64 percent as compared to a 48 percent decline in gross returns.

TABLE 2: ECONOMIC IMPLICATIONS FOR IRRIGATED LAND ASSUMING CURRENT CONDITIONS, NO IRRIGATION, AND PROJECTED CONDITIONS, UVALDE COUNTY, TEXAS

	1984 Base	1984 No Water	2040[a] Lift	2040[b] Lift
		($1,000,000)		
Net Returns	9.4	3.4	9.7	7.2
Gross Returns Irrigated	18.8	0.0	16.2	10.8
Gross Returns Dryland	9.2	14.5	9.8	11.6
Total Gross Returns	28.0	14.5	26.0	22.4

[a]Represents 100 percent irrigation application efficiency under 2040 lifts.
[b]Represents 60 percent irrigation application efficiency under 2040 lifts.

Under the year 2040 groundwater conditions and improved application efficiency, net returns increased by three percent from the 1984 base. When groundwater availability is compared, about 60 percent of the groundwater incurred a pumping lift increase of approximately 100 feet. With an irrigation application efficiency improvement by 2040 from the current 60 percent to 100 percent, net returns were estimated to increase by three percent even though the increase in lift increased the cost per unit of irrigation water. Although net returns showed a slight increase, gross returns declined by $2 million. This decline was due to cropping pattern shifts and changes in total water use patterns including a substantially reduced allocation of water. The 1984 groundwater availability to agriculture (no effect due to San Antonio pumping) with 100 percent application efficiency was not evaluated.

Under the 2040 groundwater conditions and 60 percent application efficiency, net returns declined by 23 percent from the 1984 base, and 26 percent from the 2040 case with 100 percent efficiency. The direct value of improving irrigation efficiency from 60 percent to 100 percent is estimated at $2.5 million for net returns and $3.6 million for gross returns.

Annual fixed costs of the irrigation systems were assumed the same for 60 and 100 percent efficiency. The increase in net returns to obtain 100 percent application efficiency could be viewed as the breakeven or maximum annual cost above the current system that farmers could incur as they adopt the higher efficiency systems. The annual increase in net returns was approximately $70 per irrigated acre. With an application efficiency of 60 percent, average water use per acre of irrigated land was 25.6 inches compared to 15.6 acre-inches under 100 percent application efficiency.

Regional input-output model application to each linear programming scenario permitted estimation of the impact on the regional economy for alternative groundwater levels and efficiency conditions. These agriculturally related impacts relative to the 1984 base are presented in Table 3.

TABLE 3. REDUCTION IN AGRICULTURALLY RELATED REGIONAL ECONOMIC ACTIVITY FROM ALTERNATIVE IRRIGATION SCENARIOS COMPARED TO 1984 BASE, UVALDE COUNTY, TEXAS

Scenario	Agricultural Gross Returns	Regional[a] Business Activity	Uvalde County Business Activity
		($1,000,000)	
No Irrigation	−13.5	−32.3	−23.1
2040 Lift with 100% Efficiency	−2.0	−4.8	−3.5
2040 Lift with 60% Efficiency	−5.6	−13.4	−9.7

[a]Refers to the five-county region.

An examination of the impact of dryland and irrigated agriculture suggested comparable final demand multipliers of 2.40 and 2.39, respectively. Given these multipliers, one can obtain an estimate of the economic impact of improving irrigation application efficiency for the region. The total (direct, indirect, and induced) impact of improving irrigation efficiency from 60 percent to 100 percent by 2040 for the study area was estimated at $8.6 million per year.

To provide insight into the distributional impact on the local economy, Table 4 identifies the principal sectors affected by irrigated agriculture. The primary sectors in Uvalde County were households, finance and insurance, utilities, and other retail trade. The total net economic impact of irrigation in Uvalde County was approximately $23 million, or about five percent of total county economic ac-

TABLE 4. ECONOMIC IMPACT ON MAJOR SECTORS ATTRIBUTABLE TO IRRIGATED AGRICULTURE IN UVALDE COUNTY, 1984

Local Sector[a]	Value[b]	Percent	Regional Sector[c]	Value[b]	Percent
Households	7.3	31.7	Wholesale Trade	1.1	12.2
Finance and Insurance	2.0	8.6	Other Services	.8	8.8
Utilities	1.8	7.8	Food and Kindred	.6	6.6
Other Retail Services	1.4	6.1	Transportation	.4	4.4
Health	.5	2.2	Petro. Refining	.3	3.3
Educ. Services	.5	2.2	Chemicals	.2	2.2
Ag. Services	.4	1.7	Forestry	.1	1.1
Construction	.3	1.3	Trans. Equipment	.1	1.1
Eating and Drinking	.2	.8	Communication	.1	1.1
Other Sectors	8.4	36.5	Other Sectors	4.4	48.8
Total	23.0		Total	9.0	

[a]Local refers to Uvalde County with total economic activity of $445 million.

[b]Value expressed in $ million.

[c]Refers to the five-county region but primarily San Antonio with total economic activity of $31 billion per year.

tivity of $445 million.

Additional economic impacts of irrigation in Uvalde County were for goods and services, primarily in San Antonio, which impacted wholesale trade, other services, food and kindred products, and transportation. About $9 million of economic activity from irrigation in Uvalde County affected the San Antonio area, accounting for .03 percent of the $31 billion economy of San Antonio. These results indicate that irrigated agriculture is responsible for over five percent of economic activity in Uvalde County compared to only 0.03 percent in San Antonio.

IMPLICATIONS

With lift projected to increase from 1984 to 2040 and irrigation efficiency improved from 60 to 100 percent, the results from this study suggest minimal impact to producer net returns but a significant decline in gross returns. This reduction in total output primarily affects the local business community in the form of reduced demand for hired labor, irrigation inputs, machinery needs, etc. This suggests that business leaders in Uvalde County will have a strong economic incentive to restrict San Antonio pumping to maintain agricultural output levels.

Although agricultural net returns showed a slight increase with 100 percent application efficiency, producers in the area also have an economic incentive to restrict groundwater pumping by San Antonio. With improved application efficiency and the greater quantity of groundwater available without San Antonio's influence, farmers would be able to capture a greater return from the adoption of new technology rather than having to adopt just to maintain net returns at current levels. If producers are unable to adopt improved irrigation application technologies, their net returns are projected to decline by 23 percent. This would result in a decline in Uvalde County business activity of approximately 10 million dollars per year. This sets a scenario whereby there is strong economic incentive for a cooperative political effort by Uvalde businessmen and irrigation farmers to influence Texas water allocation.

A major issue related to the Edward's Aquifer is an increasing rate of withdrawal and the related impacts on water quality, recreation, costs, and other factors. An acceptable annual pumpage rate could be established based on rainfall and minimum springflow requirements. With an established maximum on pumpage, the issue becomes one of water allocation. One market-oriented alternative would be to assign a right to a specific quantity of groundwater for alternative users. This would allow a market to be established and allow shifts among users. As an example, the city of San Antonio could purchase the right to portions of water in Uvalde County currently being used for irrigation. This does not negate the reduced level of irrigated crop output in Uvalde County but does provide payment for the water and implements a mechanism for reallocation. The payment for water may or may not be reflected in the economic activity of Uvalde County. A requirement of this modified water market involves the necessity to meter and monitor all high capacity (larger than windmill) wells in the aquifer as well as the distributional implications of the initial allocation of water rights.

Currently, the only nonmarket factor that may have an influence on groundwater withdrawal in the Edward's Aquifer is the Edwards Underground Water Conservation District. The district has a permitting system and water conservation responsibility. The permitting system is designed to provide for a minimum distance between wells but does not have jurisdiction relative to the amount of water pumped. The conservation responsibility involves education, extension, and monitoring to see that there is no "waste" of the groundwater (e.g., farmers allowing water to run out of the field and down roadside ditches).

SUMMARY

The Edwards Aquifer is characterized by large annual rates of recharge and rapid movement of water from under large irrigated areas toward San Antonio. Until the last decade, the Edwards Aquifer satisfied all users, with each exerting little influence on the other. Irrigated acreage was relatively stable and springflow varied with rainfall and pumpage but remained at a high rate.

During the 1960's and 70's, San Antonio began growing rapidly with its only water supply being the Edwards Aquifer. Given the nature of the Edwards and Texas state water law, the impact that one user might have on another became a relevant issue. This paper focused on the impact of projected San Antonio growth and resulting groundwater withdrawal rate on irrigated agriculture and the economy of Uvalde County. The purpose was to quantify the economic impact one user group could have on another group and to demonstrate the interrelationships of these Edwards Aquifer water users.

Results of this study indicate that the negative impact of greater groundwater use by the city of San Antonio is economically insignificant from a regional perspective but very important to the economy of Uvalde County. Although the results indicated that irrigated agriculture in Uvalde County could have a higher nominal net return in the year 2040, this gain would require a substantial improvement in irrigation application efficiency above the current level. In all scenarios considered, the local business economy of Uvalde County was adversely impacted by the decline in groundwater availability. The local economic sectors impacted the greatest from a reduction in irrigated activity include households, finance, insurance, real estate, utilities, and retail services.

In this study we only considered the effect of increasing water use by San Antonio on irrigation agriculture in Uvalde County. There is also an impact on springflow below San Antonio and related recreational activities and environmental effects. The results of this study begin a quantification of the externality that exists based on current Texas water law and the nature of the Edwards Aquifer.

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